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ORIGINAL ARTICLES.

I.—Morphological Studies on the Echinoidea Holectypoida and their Allies.

By Herbert L. Hawkins, M.Sc., F.G.S., Lecturer in Geology, University College, Reading.

VI. The Buccal Armature of *Conulus albogalerus*, Leske.

(PLATE XXVIII.)

1. Introduction.

Since 1824, when Charles Stokes transmitted to the Geological Society a drawing of the "buccal plates" of *Conulus*, the question of the existence and characters of the lantern in that genus has been intermittently, but inconclusively, debated. The course of this discussion may be briefly outlined here.

Desmoulins, in 1835, was of the opinion that the structures figured by Stokes were either jaws or teeth, but was uncertain as to which parts of the lantern-apparatus they might represent. Desor, in 1842, seems to have regarded these buccal plates as being the distal ends of the pyramids, being unaware that they were superficial structures with no inward prolongation. Forbes, in 1850, gave a figure of the "jaws and teeth", and in spite of the peculiar and improbable nature of these structures as depicted in his figure, echinologists of such experience as d'Orbigny and Wright accepted the drawings as representing genuine traces of the lantern. All the writers above mentioned were convinced that *Conulus* was a gnathostomatous form, basing their belief chiefly on a very reasonable analogy with other Echinoids in which the peristome is centrally placed. It is surprising that there is no record of any serious attempt at excavation of the interior of a specimen during the first fifty years of uncertainty. There is little difficulty in making preparations of the inner surface of the test of an Echinoid from the Upper Chalk, but the genius of a comparative anatomist was needed to demonstrate that fossils have insides no less than Recent forms.

Lovén and Duncan more or less simultaneously applied their energies to the elucidation of the detailed internal anatomy of fossil Echinoids, and, curiously enough, came to diametrically opposite conclusions as to the perignathic structures of *Conulus*. Lovén figured the perignathic girdle, and, while admitting the non-discovery of jaws, expressed his conviction that such organs were present. Duncan denied that there was a perignathic girdle in *Conulus*, at

least of a functional kind, and definitely stated that jaws could not have existed in the genus. He ridiculed (with some justice) the figure of the teeth given by Forbes, ascribing them to grooves made in the infilling chalk of the specimen by the use of a graving tool. As a result of his denial of the existence of jaw-structures, he detached *Conulus* from its hitherto unassailed position among the Holectypoida (Echinoconidæ) and relegated it to the group containing *Pyrina* and *Echinonëus*.

That Duncan was wrong in denying the presence of a perignathic girdle in *Conulus* is patent to all who care to develop the interior of the adoral surface of any species of the genus; it is difficult to understand how so reliable an observer could have overlooked such an obvious structure, and have succeeded in blinding the perception of another worker of the standing of W. P. Sladen. Thus his chief argument against the occurrence of jaws in the genus is based upon inaccurate observation, and, indeed, recoils. Since there *is* a perignathic girdle, and the main purpose of such a development is for the attachment of the muscles that work the jaws, the presence of the latter structures must logically be inferred until disproved—a difficult or impossible proposition. The two sole bases for such a negative argument are, firstly, the non-discovery of the ossicles in question, and secondly, the obliquely elliptical outline of the peristome.

The transfer of *Conulus* to the Echinonëidæ by Duncan may or may not be justified, but an entirely different complexion was put upon such a change by the discovery by A. Agassiz in 1909, of a fully developed lantern in a post-larval *Echinonëus*. Although this vestigial lantern is resorbed before the mouth becomes functional, its complete development at such a relatively late stage in ontogeny is a clear indication that the recent Echinonëidæ have descended from ancestors which were gnathostomatous at no very remote period. The post-larval lantern of *Echinonëus* is associated with a simple, but defined, perignathic girdle. This girdle is completely resorbed at the same stage of ontogeny as the lantern. On the inevitable hypothesis that *Echinonëus* and *Conulus* are nearly, if not directly, related, it would be expected that the latter genus should show a longer persistence of the jaw-apparatus, but that, as its ontogeny progressed, the structures should steadily degenerate. The last anticipation, so far from being justified by the known facts, is directly negatived by them. The largest specimen of *Conulus albogalerus* in which I have studied the perignathic girdle shows that structure developed into far greater complexity and perfection of detail than it presents in smaller examples. Hence it is reasonable to argue that, since the loss of the lantern in *Echinonëus* coincides in time with the complete destruction of the perignathic girdle, the retention and specialization of the girdle in gerontic specimens of *Conulus* indicates that the lantern was persistent throughout life.

In 1911 I was able to describe and figure actual teeth, with characters and proportions little different from those of *Discoides*, in a specimen of *C. subrotundus*. The specimen is fully adult, but it is strangely anomalous to find such relatively small elements as the teeth when there is no trace of the usually far more massive

pyramids. However, where there are teeth there must surely be jaws of some kind, so that it must be allowed that the species of *Conulus* were gnathostomatous at least as late as the period of the Middle Chalk.

The case is very different as regards *C. albogalerus*, the Upper Chalk species. The interior structures are readily accessible owing to the commonly soft nature of the matrix, but hitherto no indication has been found of any buccal armature save the perignathic girdle and the "buccal plates". In the paper referred to above I accepted the suggestion that the buccal plates might be curiously modified relics of the pyramids, and that the species was edentulous. One of the main purposes of this paper is to express an absolute and complete recantation of this suggestion. The arguments in the next section will, I think, suffice to account for, if not to explain, the peculiar nature of the buccal plates, and the latter description of the presumed fragments of true pyramids recently discovered will afford insight into the reason for their habitual non-preservation in a recognizable condition.

2. The Buccal Plates.

One of the most striking features of the Echinoid fauna of the Upper Cretaceous is the massiveness of the test-fabric. Such a genus as *Stereocidaris* illustrates this point very clearly; but it is most obvious in the Irregular Echinoids. A comparison between *Echinocorys* and the nearly allied recent genus *Urechinus* shows an extraordinary contrast in the thickness of the coronal plates. The "Heart-Urchins" of the present fauna are, for the most part, constructed of exceedingly delicate fabric, the test often being as thin as tissue-paper. But *Micraster* and *Hemiaster*, the Cretaceous representatives of the "Heart-Urchins", have tests of almost unwieldy thickness.

As a general rule, the Echinoids of the present day may be divided into two sections; those whose habitat is exposed, and those which live buried in sand or ooze. The former group comprises most of the Regular Echinoids, and may be illustrated, in an extreme case, by such a form as *Heterocentrotus*, in which the coronal plates may be as much as a quarter of an inch in thickness. Another type of "exposed" Echinoid is the "Sand-dollar", in which, even when the test is not very thick (as it is in *Clypeaster*), the whole fabric is supported by pillars and buttresses within. The latter group may be represented by *Echinocardium*, where the test is exceedingly thin and fragile. The difference in test-thickness is obviously, from one point of view, a mechanical adaptation to the requirements of the habitat. The strong test that will successfully resist the pounding of the waves can be almost dispensed with in the shelter of a burrow.

There is, however, small ground for believing that the surroundings of such a genus as *Micraster* were in any sense tempestuous; the reverse is more probable. So that the great thickness of the test in the Chalk Echinoids must be due to some other cause. Indeed, it would seem that they underwent excessive calcification quite independent of their mechanical needs; and this thickening was

therefore likely to affect other stereom-structures besides the actual corona. The buccal-membrane plates of *Echinocorys*, as Lambert and I have described them, are far more robust than those of similarly sized Spatangoids of the present day, although far inferior in thickness to the coronal plates. The periproctal plates of *Discoides* are equally strong.[1]

In a specimen of *Conulus albogalerus*, the interior of which is almost filled with flint, there are numerous thick, granular plates in the mealy chalk within the periproct. They are like the buccal plates in every feature except that of shape, and I have not the slightest hesitation in identifying them as the plates of the periproct-membrane. Since the periproctal plates are so enormously thickened in this species, it is only to be expected that the peristomial ones should be in a similar condition. There is, therefore, good reason for believing that the buccal plates of *Conulus* are merely the plates of the buccal membrane, and that their strange proportions are but an advanced expression of the Upper Cretaceous "mode".

[*Note inserted in proof, September* 14, 1917. — The preceding paragraphs were written in July of this year. The Editor has kindly drawn my attention to two recent papers in this Magazine which include references to the phenomenon of "super-calcification" in Cretaceous forms. One, by W. D. Lang, deals with Polyzoa, and the other, by C. T. Trechmann, is concerned with Mollusca. The Editor has also reminded me of the extraordinary superfluity of shell-substance developed in the Rudistacea in the same period. In some cases it is easy and probably correct to ascribe the secretion of apparently unnecessary mineral matter to phylogerontic over-specialization (e.g. *Parkinsonia dorsetensis* from the Bathonian, and *Clavella longæva* from the Bartonian). But in the case of the "Heart-Urchins" above mentioned, such an explanation seems impossible. *Hemiaster*, *Micraster*, and *Epiaster* represent the progressive pioneers of the Spatangina, not degenerate and superannuated relics; and a quality that affects a large proportion of a fauna, irrespective of the phylum or phylogenetic phase of the individuals, must surely have originated from some more comprehensive and fundamental cause. However, this is not the place for a discussion of the problem.]

If the foregoing interpretation of the buccal plates is correct, an important corollary follows. Lovén showed that the young *Echinocardium flavescens*, where the outline of the peristome is roughly circular, has ten elliptical plates on the buccal membrane, arranged in a complete cycle near the circumference of the aperture. In 1912 I indicated the close correspondence in most characters between the early ontogenetic stage of the buccal plating in *Echinocardium* and the "buccal plates" of *Conulus*; but hesitated to correlate the two sets

[1] The same remark applies to the periproctal plates described by F. J. North (Ann. Mag. Nat. Hist., December, 1915). His specimen is obviously a species of that Upper Chalk Caratomid genus variously called *Echinoconus* (Desor, *fid.* Lambert), *Pironaster* (Schlueter), or *Conulopsis* (Hawkins). Anyhow, the horizon from which it was collected, and all the particulars published about it, show clearly that it is not a *Discoides*.

of structures owing to the "massive character of the latter ossicles". If the foregoing argument is sound, this difficulty disappears. Hence it is with confidence, bordering on conviction, that I now express the opinion that the "buccal plates" of *Conulus albogalerus* represent the Cretaceous phase of the plating of the buccal membrane which is recapitulated during ontogeny in the earliest post-larval stage of *Echinocardium flavescens*. This does not necessarily imply a direct phyletic sequence between *Conulus* and the "Heart-Urchins"; it is rather a fresh illustration of morphic parallelism independent of actual phylogeny. But it entirely destroys the arguments put forward by me in 1911 (GEOL. MAG., p. 73), and cancels the hypothetical diagram there given (Pl. III, Fig. 8).

3. THE PERIGNATHIC GIRDLE. (Pl. XXVIII, Figs. 1–3.)

(a) *The Angle of Inclination.* (Pl. XXVIII, Figs. 2, 3.)

The elements of the girdle in the Holectypoida, when viewed from within, always show a slope outwards from the peristome, thus contrasting with those of the Regular Echinoids, which are comparatively vertical in direction. In *Conulus albogalerus*, as in *Discoides* (see Part V of this series), the greater part of the girdle reclines against, or is bevelled off from, the proximally thickened interambulacra. There are thus two roughly circular rings whose diameters may be measured: the actual peristome margin and the upper limits of the girdle. In a young specimen of *C. albogalerus* (Fig. 3), where the diameter of the adoral surface is about 25 mm., the former diameter is *c.* 4 mm. and the latter *c.* 6·5 mm. In a gerontic specimen (Fig. 2), with an adoral diameter of about 48 mm., the corresponding measurements are 5 mm. and 9 mm. respectively. Reducing these measurements to a proportionate scale, we arrive at the following result:—

	Diam. of peristome.	Diam. of top of girdle.
Young specimen . .	1	1·62
Old specimen . . .	1	1·80

Specimens of intermediate sizes give proportionate results between these two extremes. Thus the obliquity of the girdle appears to increase with age. However, the vastly greater thickness of the interambulacra in the old specimen automatically increases the "splay" of the bevelling, and in reality the obliquity of the girdle is considerably less in the gerontic than in the small specimen. The approximate angles between the girdle and the plane of the adoral surface in the two examples are as follows:—

Young specimen	12°
Old specimen	25°

The actual inclination of the girdle in the fully grown example is thus more than twice as steep as that in the young one. This result has been checked by the measurement of the angles in twenty-eight specimens of intermediate size. It is somewhat surprising to find a decrease in obliquity during the growth of

Conulus—the reverse would have been anticipated. From *Plesiechinus* onwards the record of the perignathic girdle is one of ever-increasing obliquity, and in the Clypeastroids the angle between the plane of the adoral surface and a line joining the peristome-margin to the top of the girdle is very acute. The reversal of the trend of evolution in *Conulus* would thus seem to indicate that there is no direct phyletic course from the Holectypoida to the Clypeastroida by that route; a conclusion that is supported by most other morphological indications. But it is a reversion towards the "Regular" character, and as such might be held to imply that the jaws of *Conulus* "improved" in quality during ontogeny. On the other hand, it seems equally logical to suggest that the continued thickening of the proximal parts of the interambulacra prevailed over the failing girdle, so that its increased slope is an expression of its waning functional importance. On general grounds, I incline to accept the latter alternative as the probable explanation of this anomalous feature.

(b) *The Structure of the Girdle.* (Pl. XXVIII, Figs. 1 and 2.)

The general characters of the girdle of *C. albogalerus* are well known, and little in the way of description needs to be added to the account given by Lovén in *Echinologica*. The chief problem is concerned with the interpretation of the observed structures. For this purpose I have chosen the very large specimen to which reference has been made in the preceding section, since this shows all the details of the girdle with an exaggerated clearness. The peristome is elliptical, with its long axis in the direction 3, I.

The general plan of the girdle strikingly resembles that of a Tudor rose. The five "petals" rise sharply from the peristome-margin in concave and embayed escarpments. Outside them the interambulacra rise to a slightly greater height, and then gently slope down towards the ambitus. The "petals" are separated from one another by the deep and narrow sulci of the ambulacra. The lateral margins of a "petal" consist of slender, projecting processes, based upon the bordering ambulacra, and visibly sutured to the main structure. Each process culminates distally in an almost spherical and glossy knob, which projects upwards and inwards beyond the general level of its surroundings. The "petal" itself may be considered to consist of three parts. There is a central prominence on the peristome border, rising sharply and culminating in a bevelled crest. Above this the chief part of the "petal" rises in a deeply concave slope, bisected by a median carina, which, though prominent, is also concave in the upward direction. At the top of the structure, overhanging the bays and carina of the main surface, is an almost flat area which slopes very gently towards the peristome, and has an imperfectly defined rim distally. (This platform is practically non-existent in smaller examples.) Beyond the platform the inter-ambulacrum rises a little above the sulcate suture which bounds the girdle, and then falls away gently towards the ambitus. The only sutures that I have been able to detect with certainty are (1) those between the bordering processes and the "petal", (2) a crescentic

boundary suture between the platform and the normal inter-ambulacrum, and (3) an interradial suture bisecting the carina. In addition, there appears to be a suture between the prominence and the carina, but it is by no means clear, although the junction between these two parts of the structure is very sharply defined.

The only additional ingredient of the girdle is the narrow, but proximally striking, carina which occupies the line of the perradial suture. The bulbous proximal end of this carina extends inwards beyond the normal circumference of the peristome. It is presumably developed for the stiffening of the thin coronal plates of the ambulacrum, which would otherwise seriously weaken the cohesion of the adoral parts of the test; but it may possess a further function, to which reference will be made later. The carina covers and quite obliterates the perradial suture.

(c) *The Homology and Function of the Structures.*

A comparison of the elements of the girdle of *Conulus* with those of *Discoides* (see Part V of this series) reveals an essential similarity. The processes are quite obvious. The central interradial prominence on the peristome-border is clearly the "true ridge", while the remainder of the interradial structure represents the "false ridge". Assuming the existence of a lantern, the retractors will have been attached to the upper parts of the processes, and the protractors to the true ridges. The false ridges, by analogy with those of *Discoides*, will have served as a rest or slide for the inclined pyramids. The only serious difference in the girdle-structure between *Discoides* and *Conulus* is found in the false ridges. In *Discoides* each false ridge is practically an inclined plane, with a very faint median concavity. In *Conulus* it has a concave surface, with a median carina, deeply excavate sides, and an overhanging summit. I believe that these three features are all to be associated with the curious nature of the buccal plates. The pyramids of the lantern would rest upon the true ridges and the gently inclined summits of the false ridges, and so would leave considerable spaces between themselves and the deep hollows, and even the carinæ, of the slopes of the false ridges. When the mouth was opened the massive buccal plates would inevitably need to be shifted, and it is hard to imagine more likely or suitable places for them than the deep slots in the false ridges. The median carina and the projecting edges of the processes would ensure their sliding in the right direction (so as to avoid confusion with the protractor muscles), and the proximal bulb of the perradial carina might have served to start them on their proper course when retracted. Thus the view put forward by me in 1911 as to the movement and disposal of the buccal plates still holds good, although I now disbelieve in the homology between those plates and the lantern-pyramids.

If the lantern was of a "flaring" nature (as would be probable in view of its character in *Discoides* and the Clypeastroida), it must perforce have come very near to, if not into contact with, the upper part of the perignathic girdle. Whether it articulated with the glossy knobs at the summits of the processes is a matter of doubt,

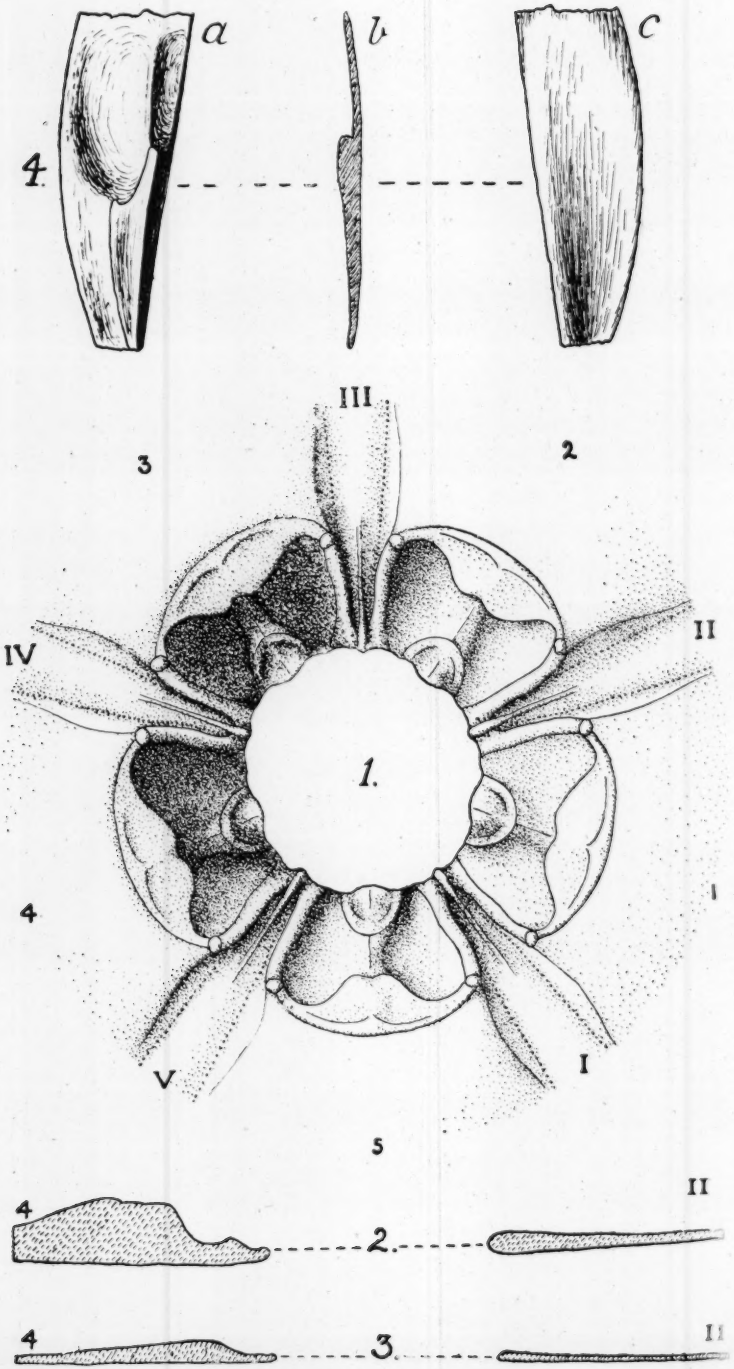
but such an arrangement would be in keeping with the Clypeastroid character. But it might well have reclined upon the "platform" of the false ridge, bridging across the concavity between that and the peristome margin, and leaving space for the buccal plates to be retracted behind it. Such speculations are, however, of little value until more is known of the structure of the pyramids.

4. The Lantern.

When the chalk infilling of a test of *Conulus albogalerus* is brushed down, it proves to be surprisingly full of small, usually fragmentary, pieces of calcite. These are naturally often portions of Foraminifera, Polyzoa, or Pelecypod prisms that have drifted in with the ooze. But the fact remains that these fragments seem more thickly scattered through the internal than the external matrices. I have destroyed several hundreds of specimens of *C. albogalerus* in my hitherto vain endeavours to find the jaws; and in one example only, from the top of the *M. coranguinum* zone near Kingsclere, have any reasonably satisfactory portions been observed. Their nature explains the peristent way in which they elude recognition. They are small, and so delicate in texture that they are translucent, and the friction due to even a soft tooth-brush readily shatters them, if applied at random. In the specimen here noted the chalk within the test was almost powdery in consistency, and was removed with a camel's-hair brush. Two or free fragments, which seem to represent pyramids, were extracted, but they are so broken and difficult to orientate that I prefer to postpone full description of them in the hope of procuring better specimens.

I have selected one of the fragments (3 mm. long and about 1 mm. broad) as indicative of the general characters of these interesting ossicles. It is shown on Pl. XXVIII, Figs. 4, *a*, *b*, *c*, from three points of view, *a*, *b*, and *c*. How far its outlines are natural or are the product of fracture is difficult to determine. The fragment is roughly triangular, and excessively thin. The top and bottom are both broken. One side is gently crescentic in shape, and the other almost straight. I believe that the curved side is a natural margin, but whether the straight edge is natural or the result of cleavage I cannot determine. One surface (*a*) shows a carina passing longitudinally near to the straight margin at the broader end of the surface, and separating two ovoid excavations. Towards the narrower end the ossicle is thicker, the carina less prominent, and one side of the surface is gently bevelled. A comparison of this figure with that of the alveolar view of a maxilla of *Discoides* (Geol. Mag., 1909, Pl. VI, Fig. 5) shows an almost startling resemblance. If the straight edge of the *Conulus*-ossicle is taken to be a cleavage line, cutting the maxilla vertically and removing the inward extension of the inter-pyramidal joint-face, the likeness between the figures is complete in all save proportions. The two figures are supposed to be similarly orientated.

Fig. *b* is a view of the (?) cleavage margin of the ossicle. It shows the extreme tenuity of the structure at the broad, excavate end, and its superior massiveness at the narrow end.


a
b
c
4
III
3
2
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IV
1.
4
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Fig. *c* shows the opposite side of the ossicle to that drawn in Fig. *a*. It is not quite parallel to that side, but makes a very acute angle with it. Save for a slight median sulcus, increasing in depth towards the narrow end, it is plain. It is very suggestive of the external surface of the maxilla of *Discoides* (loc. cit., Fig. 2), but only if the straight edge of the ossicle is regarded as the symphysial margin instead of a cleavage line.

It is difficult to imagine that this fragment can be other than a part of a maxilla, and still more difficult to doubt that it belonged to the specimen in which it was found. Other fragments include one which suggests the existence of alar expansions like those of the Clypeastroida (with a similarly reticulate character), and another that is presumably part of a stirodont tooth. For the reason stated above I prefer to leave all detailed discussion of these structures to the future. The specimen figured is sufficient to indicate the grounds for my belief that the lantern of *C. albogalerus* has been found at last.

5. Summary.

The perignathic girdle of *Conulus albogalerus* is shown to resemble closely that of *Discoides*, with modifications due to the greater degree of thickening of the interradial coronal plates and to the massive character of the buccal plates. These are considered to be the true plates of the buccal membrane, and to have been capable of retraction into the deep sockets of the false ridges of the girdle. The existence of a lantern is inferred as a result of arguments based upon the known characters of the girdle and upon analogy with related types. Certain imperfect ossicles found within the test of a small specimen are considered to represent portions of the lantern; and one, here figured, seems clearly to be a fragmentary maxilla similar in all essentials to that of *Discoides*, but differing in shape and proportions. Further discussion of the presumed lantern is deferred until better material is acquired.

The next paper in this series will deal with the perignathic structures of the Holectypoida as a whole, with a discussion of the internal characters of the peristomes of some early Spatangoida.

Explanation of Plate XXVIII.

Fig.

1. Perignathic girdle of a gerontic specimen of *C. albogalerus*. ×*c.* 6. All sutures except those at the sides of the processes are omitted. There is a suture down the middle of each false ridge, but the median lines on the true ridges represent the crests of carinæ, not sutures. The outlines of the various parts are slightly emphasized, but otherwise the figure is not diagrammatic.
2. Section along the axis 4, II, of the same specimen. ×*c.* 6.
3. Section along the same axis of a smaller specimen. ×*c.* 9. The "platform" of the false ridge is indistinguishable.
4. *a*, *b*, *c*. Fragment of presumed maxilla from the interior of a small specimen of *C. albogalerus*. ×*c.* 14. *a*. ? Alveolar view, showing ? distal hollows, ? symphysial surface (on the left), and ? dental slide (on the right). *b*. Side view along the straight edge of the fragment. *c*. ? Outer view, showing the shallow sulcus deepening towards the narrow (? proximal) end.

II.—Observations on the genus *Polymorphites*.

By A. E. Trueman, M.Sc., University College, Nottingham.

In 1843 Simpson published a description of a Yorkshire Ammonite previously named *Ammonites trivialis* in Bean's manuscript.[1] A few years later Quenstedt described a number of small continental Ammonites of similar character as *A. polymorphus*, which he further divided into the varieties *lineatus*, *costatus*, *interruptus*, *mixtus*, and *quadratus*. The specimens he then figured must be taken as his types[2]; in a later work[3] he showed many more examples which he referred to the same species; all these have small, evolute shells, but few other common characters, so that the name *polymorphus* was fully justified. For example, the illustrations given as *Ammonites polymorphus mixtus* include forms with round or square whorls, with nearly straight or with curved ribs, which may pass across the venter with or without a forward bend, or may be suppressed entirely on the venter. The specimens figured probably include young examples of several different genera.

Sutner and Haug[4] systematized our knowledge of these fossils and established the genus *Polymorphites*, while Simpson's specimens have recently been figured and described by Buckman[5] as *P. trivialis*, Bean–Simps.; *P. mixtus*, Qu.; *P. jupiter*, d'Orb. The following notes are mainly concerned with these three species. Most of the specimens used in this work were pyritized casts obtained from the Lower Lias clays on the tunnel heaps at Old Dalby in North Leicestershire; accordingly their precise horizons cannot be given. With them there were also found *P. caprarius*, Qu., *P. quadratus*, Qu., and other fossils of the *valdani*-zone. For permission to make use of the abundant material in the collections at University College, Nottingham, and for much help in the work, I desire to express my thanks to Professor H. H. Swinnerton. Mr. S. S. Buckman has also kindly given valuable suggestions.

Comparison of the Species.

Polymorphites trivialis is a costate form; occasionally a strongly ribbed example may show a row of elongate tubercles on the external margin. The venter may be somewhat angular, thus resembling *P. caprarius*, but frequently it is more or less rounded in the adult, when the form may approach *P. quadratus*.

P. mixtus is less strongly ornamented; in the development of this species the shell is at first smooth, then striate, and in the adult subcostate to costate. In this respect it is intermediate between *P. trivialis* and *P. jupiter*, which is an evolute simple form, smooth until a diameter of about 4 mm. is attained, when slightly curved striæ are developed. The developments of these forms are compared

[1] M. Simpson, *Monog. Lias Ammonites*, London, 1843.
[2] F. A. Quenstedt, *Die Cephalopoden*, 1849, pp. 86–7, tab. 4.
[3] F. A. Quenstedt, *Die Ammon. de Swäb. Jura*, 1885.
[4] E. Haug, "Ueber die Polymorphidæ": Neues Jahrb. f. Min., 1887.
[5] S. S. Buckman, *Yorkshire Type Ammonites*, vol. i, No. 53, 1912.

in the table. The numbers there given refer to the ornament cycle of Buckman.[1]

Diam. (mm.)	P. *trivialis*.		*P. mixtus*.		*P. jupiter*.	
25	Tuberculate	5*	Costate	4	Striate	2
20	Costate	4	Costate	4	Striate	2
15	Subcostate	3	Subcostate	3	Striate	2
10	Subcostate	3	Subcostate	3	Striate	2
5	Striate	2	Striate	2	Smooth	1
2	Smooth	1	Smooth	1	Smooth	1
1	Smooth	1	Smooth	1	Smooth	1

Occurring with these species at Old Dalby is a form which outwardly resembles *P. jupiter*, but which has costate inner whorls and is probably a catagenetic offshoot of *P. trivialis*. A similar example was figured by Buckman,[2] who considered it to be *P. jupiter* showing temporary catagenesis, but who now suggests[3] that the persistence of the striate ornamentation indicates that it is a different species. For convenience this degenerate form is here referred to as *P.* cf. *jupiter*.

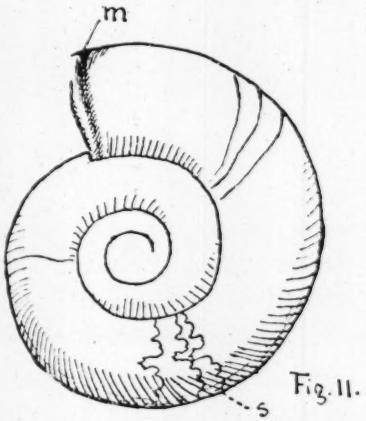


Fig. 11.

Fig. 11.—*P. mixtus*. *s*, last suture; *m*, mouth margin.

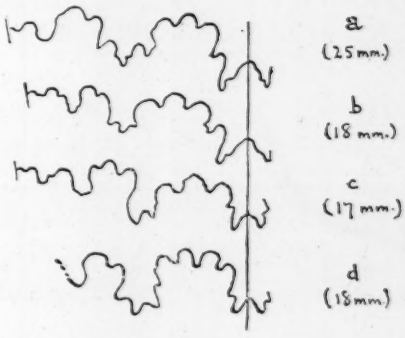
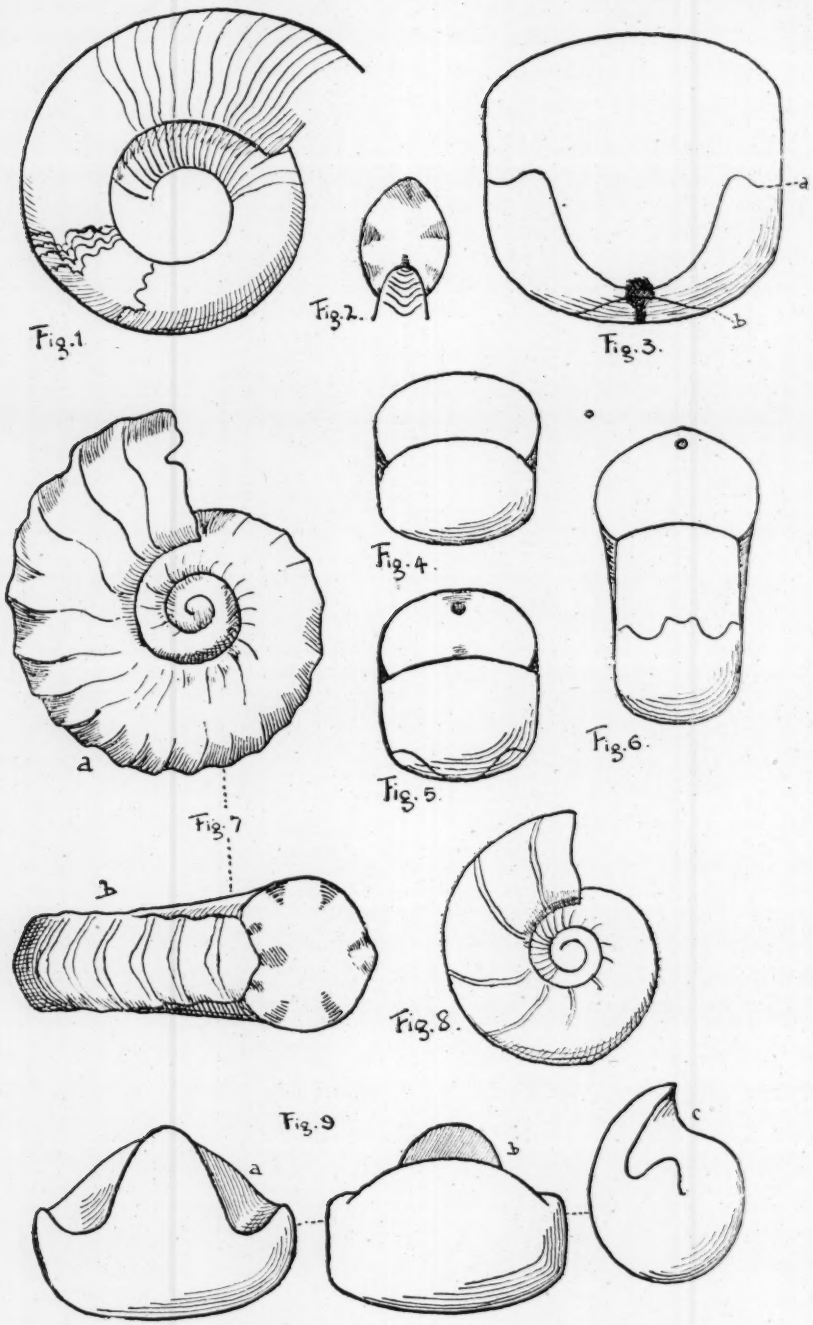


Fig. 12.—Adult sutures of *Polymorphites*. *a*, *P. trivialis*; *b–d*, *P. mixtus*.

The adult sutures of some specimens of *P. trivialis* and *P.* cf. *jupiter* have saddle terminations more rounded than others (Fig. 12*a*), and the external saddle may have either three or four terminal folioles. In nearly all cases the last three or more sutures are closely crowded (Figs. 1, 11), a feature which is also shown in some of Quenstedt's figures.

In examples of *Polymorphites* the mouth margin is not usually preserved, but a specimen of *P. mixtus* shows a mouth border preceded by a constriction (Fig. 11); in this case the length of the body-chamber is half a whorl.

[1] S. S. Buckman, *Yorkshire Type Ammonites*, vol. i, p. xiii.
[2] Ibid., No. 53*c*.
[3] *In litt.*, August 3, 1917.



The Development of *Polymorphites jupiter*. Fig. 1, adult (30 mm.); Fig. 2, arched venter (at diam. 8 mm.); Fig. 3, early chambers, × 72; Figs. 4–6, successive stages (diam. ·7, ·75, 1·2 mm.); Fig. 7, costate stage (2·8 mm.); Fig. 8 (8 mm.); Fig. 9, protoconch, × 63.

J. F. Blake[1] pointed out that in the Yorkshire examples of *A. trivialis* the inner whorls are not usually preserved. The earlier chambers, however, are present in occasional specimens from Old Dalby, and the development may be studied without much difficulty in *P.* cf. *jupiter*.

The Development of *Polymorphites* cf. *jupiter*. (Figs. 1–9.)

The protoconch, which is not often preserved, has axes of ·56 mm. and ·4 mm. respectively, and shows the usual angusti-sellate characters. The whorl section is depressed in the early stages (see Figs. 4 and 5), and does not become as high as wide until a diameter of 4 mm. is reached. Before this time (at about 1 mm. diameter) a somewhat angular (convexi-fastigate) venter is developed (Fig. 6), and at a diameter of 2 mm. low curved folds appear. During the next whorl the venter becomes more angular and the folds more prominent, especially on the venter, where they bend sharply forwards (Figs. 7*a*, *b*), causing a superficial resemblance to the crenulate keel of the Amaltheidæ.

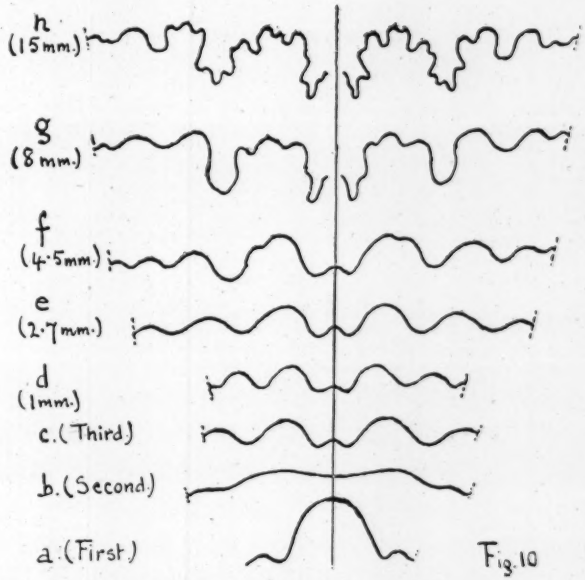


Fig. 10.—Sutural development, *P.* cf. *jupiter*.

This costate stage persists until the shell attains a diameter of 6–9 mm., when it is succeeded by a subcostate stage, low folds alternating with striæ of similar form (Fig. 8), which presently are developed to the exclusion of the folds (Fig. 1); by this time whorl height appreciably exceeds whorl thickness and the venter is rounded or slightly angular. In later life the striæ become less prominent.

The account of the development just given applies to most of our

[1] In Tate & Blake, *The Yorkshire Lias*, 1876, p. 292.

specimens. In a number of cases slight modifications occur; for example, in some forms striæ are developed before the low folds (as in Fig. 8). In one example, the outer whorl of which was similar to *P. jupiter*, the inner whorls to a diameter of 9 mm. had the characters of *P. caprarius*. This suggests that the forms known here as *P.* cf. *jupiter* may be polyphyletic, being catagenetic descendants of several more highly ornamented forms.

The sutural development (shown in Figs. 10*a–h*) does not vary greatly in the different species considered. The first suture shows the narrow external or azygous saddle flanked by small lateral saddles (Fig. 10*a*). In the second suture this external saddle is divided by a low ventral lobe, a primitive stage which is omitted in the development of more highly specialized ammonites. In the third suture the ventral lobe is much deeper and is already divided by a small median saddle; the external and lateral saddles are by this time higher, though still not so high as wide (Fig. 9*e*). Not until the diameter of 1 mm. is attained is there any marked advance on this stage, a small auxiliary saddle being then developed (Fig. 10*d*). At the diameter of 4·5 mm. another auxiliary is present and the first indication of frilling has appeared on the dorsal side of the external saddle. By the fifth whorl (at a diameter of 8 mm.) the external saddles show the well-marked divisions which are characteristic of the adult. It will be noticed that the lateral elements appear to have swung forwards, so that the anterior borders of the external and lateral saddles are approximately level, although the external saddle is much larger than the first lateral.

Connexions with other Genera.

Several views have been expressed concerning the systematic position of the species considered. For instance, Blake referred *A. trivialis* to *Amaltheus*, the knotted keel of the young possibly being his main reason, while Wright referred them to the comprehensive genus *Ægoceras*.

Important progress in studying the relationships of *Polymorphites* and allied forms was made by Haug, who showed that the "keeled" young was quite unlike a young *Ægoceras*, and suggested that *Polymorphites* was descended from *Agassiceras miserabile*. The simple but wrinkled suture shown by this ammonite, however, can scarcely be compared with the early suture of *Polymorphites*. Haug further suggested that the evidence of genetic connexion is confirmed by the occurrence of asymmetric sutures in each of these genera, but this character is rarely sufficiently constant to be used as a test of affinity, and, moreover, asymmetry is not common in British specimens of *Polymorphites*.

More recently Buckman has suggested that *Cymbites* is the radical of *Polymorphites*,[1] and the facts of development support this view. Thus, the shell form of *P. jupiter* at a diameter of 1 mm. closely resembles that of *Cymbites globosus* at 10 mm. diameter. A comparison of the sutural developments of *P.* cf. *jupiter* and *C. globosus* (see

[1] S. S. Buckman, "On the genus *Cymbites*": Geol. Mag., 1894, p. 361.

Fig. 13 [1]) affords additional evidence. In each of these two forms the high median saddle of the first suture gives place in the second suture to a broad, shallow median lobe, which is in each case divided by a median saddle in the third suture. The development of folioles and their arrangement in the adult suture point to a close relationship between *Polymorphites* and *Cymbites*. The length of the body-chamber in the two genera is about half a whorl, although *Cymbites* appears to have a different form of mouth from that of *Polymorphites*.[2]

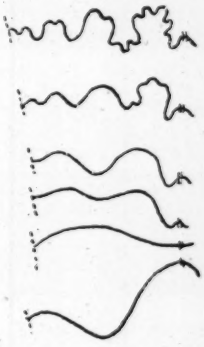


Fig. 13.—Sutural development of *Cymbites globosus* (after Branco).

Cymbites lævigatus is in some respects intermediate between *C. globosus* and *Polymorphites* in being more evolute, feebly costate, and often having a slightly angular venter, which is not developed, however, until a diameter of 12 mm. is reached.[3] It is thus extremely probable that *Polymorphites* is derived from a form resembling *Cymbites globosus*, possibly through *C. lævigatus*. Such a position near the radical stock would account for the primitive characters noted, and for the amount of variation in different representatives of the genus.

III.—The Pahang Volcanic Series.

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(WITH PLATE XXIX AND A MAP, PLATE XXX.)

Introduction.

THE name Pahang Volcanic Series was given by Mr. J. B. Scrivenor to those eruptive and intrusive rocks of the Malay Peninsula which are older than the Mesozoic granite, and the rocks were described by him in *The Geology and Mining Industries of Ulu Pahang*, 1911, ch. xi. As the name implies, the series is most strongly developed in Pahang, but it is also developed to a greater

[1] After W. Branco, *Beit. Entwick. foss. Ceph.*, Th. i, tab. xii, 1879.
[2] E. Dumortier, *Dépots Bassin Rhône*, pt. iii, pl. xviii, figs. 3, 4, 1869.
[3] A. Hyatt, "Genesis Arietidæ": Smithsonian Contributions, No. 673, pl. viii, fig. 10, 1889.

or less extent in Singapore *[1] Island,[2] Johore *, Negri Sembilan *, Selangor *, and Perak *, and possibly also in the more northern states, Kedah *, Kelantan *, and Trengganu *. The present account deals for the most part with the main development in Pahang, and most of the information was obtained on two trips, one to examine the railway-cuttings from Gemas * to Kuala Lipis, and the other to examine outcrops over a distance of about 100 miles in the rivers Jelai and Pahang, from Kuala Lipis to Mengkarak.

A large part of the first trip was fruitless, for the railway cuttings over a distance of 80 miles in Negri Sembilan * and part of Pahang were so much weathered that they conveyed practically no information. For instance, it was impossible to determine whether certain sandy strata intercalated with shales near Kerdau railway-station were weathered quartzites or volcanic-tuffs, and it is possible that the Gondwana outcrop extends further to the north than is represented on the map, whereas, on the other hand, it may be incorrect to leave the 20 miles of river and railway below Kuala Tekal barren of Pahang Volcanic Series rocks, and indeed, in the sketch-map attached to the above memoir, Mr. Scrivenor indicated their presence along this stretch. Between Kuala Krau and Kuala Lipis, and particularly along that part between Kuala Tekal and Kuala Lipis, there were some excellent exposures, but at the time when the trip down the Rivers Jelai and Pahang was taken the river was not low, and so many exposures which had previously been described by Mr. Scrivenor were not seen on this occasion.

Great use has been made of the information and specimens collected by Mr. Scrivenor from different rivers and from the Benta–Kuantan road, and the occurrences of Pahang Volcanic Series rocks represented on the Map (Plate XXX[3]) in all districts, excepting the railway and Rivers Jelai and Pahang, have been copied from his 1911 sketch-map.[4]

Associated Rocks.

The Pahang Volcanic Series is associated with the sedimentary rocks of the Raub, and also, to a less degree, with Gondwana rocks. The Raub Series is the more prominent in the Pahang Valley, and consists of limestones and calcareous shales, the colour of the limestones varying from white to black, according to the quantity of carbon they contain. The greater part of the Gondwana rocks is made up of quartzites, grits, and shales, the exposures of quartzite being usually weathered to sandstone except in fresh cuttings, though occasionally "core-boulders" of hard quartzite are found. In many parts of the Peninsula cherts are seen at the base of the Gondwana rocks, and in Negri Sembilan * several exposures east of the Main

[1] An asterisk marks the names of all those places in Malaya mentioned in the text which are outside the area shown on the accompanying Map, Plate XXX.

[2] Described by Mr. Scrivenor in the Geol. Mag., Dec. V, Vol. VI, pp. 17–22, January, 1909.

[3] The Map will appear in the second part of the paper in November.

[4] The photographs of rock-sections illustrating this paper (Plate XXIX) were taken by Mr. Scrivenor, to whom I now tender my best thanks.

Range show cherts interbedded with quartzites, that is, with Gondwana rocks. A chert band at Lubok Plang, associated with Raub rocks, indicates that there was a series of cherts older than that associated with Gondwana rocks, and the occurrence in Gondwana conglomerates of pebbles of chert which had been veined before being rounded as pebbles shows that there was a considerable unconformity after the Raub period and before the deposition of the Gondwanas.

The relations of the sedimentary rocks of the Peninsula to one another are expressed shortly in the following table. No Tertiary rocks have been seen in Pahang.

Series.	Nature of Rocks.	Remarks.
	Recent deposits.	Including coastal alluvium, etc.
	Unconformity.	
Tertiary.	Shales and sandstones, with coal seams, at Rantau Panjang*, Enggor*, and Perlis*. No outcrops known in Pahang.	Tertiary plant remains.
	Unconformity.	The main range granite was intruded, with folding and shearing of the sedimentary rocks.
Gondwana Rocks.	Shales and quartzites. Pahang Volcanic Series and cherts. The Myophorian sandstone.	With fossils of Rhætic period.
	Unconformity. Boulder-in-tuff deposits formed now?	Volcanic activity was in full swing.
	The Pahang Volcanic Series. Cherts (in situ at Lubok Plang, Pahang River, and as pebbles in Gondwana quartzites all over the Peninsula). Shales and limestones (in L. Selangor* and east of Negri Sembilan*). Altered shales (talc schists and phyllites), west of Negri Sembilan*. This series may be younger than the limestones.	Some Raub shales in Pahang contain Permian fossils. Fossils from limestone in Pahang are Carboniferous.

Fossils are rarely met with, but a collection made by Mr. Scrivenor from a limestone hill near Kuala Lipis indicates a Carboniferous age for the Raub Series, and the fossiliferous Myophorian sandstone at the base of the Gondwana rocks corresponds to the Rhætic period. Some fossils in shales at Lubok Sukum indicate a Permian age for the beds there. Shales and sandstones, i.e. Gondwana rocks, are exposed near here, but at the time the trip was made down the Pahang River the fossiliferous shales were not exposed, and Mr. Scrivenor, who collected the fossils, was of the opinion that they occurred in Raub rocks. The field evidence of the relations of the Raub shales and limestones in Pahang suggests that they constitute an alternating series, and that some Raub shales are older, whilst others are younger, than the Raub limestones, but in other districts, for instance in Negri Sembilan*, there is a possibility that the upper part of the Raub Series consisted of calcareous shales which are now (in Negri Sembilan) altered to phyllites and talc schists.

Distribution of Pahang Volcanic Series throughout the Peninsula.

The Map (Plate XXX) indicates the known places of occurrence in the area of greatest development in the Peninsula, but it must be remembered that little is known of the country not actually penetrated by rivers, roads, or railway. All places mentioned in the text that are not marked on the Map occur outside this area.

It is clear that volcanic activity was stronger during the Raub period than during the deposition of the Gondwana rocks which followed. In the south of Negri Sembilan* and north of Johore* there is a considerable development of Pahang Volcanic Series tuffs, but few lavas or intrusive rocks have yet been noted there. In Singapore* certain core-boulders of quartz-porphyry and dolerite have been examined by Mr. Scrivenor,[1] but as the rocks do not occur in situ nothing can be said about their age. Similar core-boulders have been found on the Kuala Lumpur* to Bentong* road where it crosses the Main Range, and their age too is rather a matter of doubt, but there is little doubt as to the age of an igneous rock like a lava which is found near here interstratified with chert being that of the Pahang Volcanic Series. There are numerous exposures of a porphyritic rock which forms the greater part of the hill-cap, and is seen in road-cuttings both on the Selangor* and Pahang side of the Main Range. It contains abundant colourless rhombic and monoclinic pyroxene, biotite, quartz and felspar (oligoclase and labradorite) set in a fairly fine-grained mosaic of felspar (some of it labradorite) and quartz. This rock, which may be termed granite-porphyry, and the quartz-porphyry which occurs as core-boulders, are both fresh, and contain no calcite or epidote, but they show signs of considerable shearing.

The quartz-porphyry is seen in situ at Jeram Gading*, a tributary of the River Klang*, near its source (outside the area shown on the Map), and forms a steep gorge about four miles upstream from the point where the tributary flows into the main river. In this gorge

[1] Geol. Mag., Dec. V, Vol. VI, No. 535, January, 1909.

the quartz-porphyry is seen to be traversed by numerous good joint planes which are much more strongly developed than, for instance, is the case in granite, and their distribution at rather irregular intervals causes the rock to separate into angular blocks of very different sizes. Here is seen what is sometimes noticed in granite, namely, that the transition from unweathered hard rock to soil is very abrupt and that there is no partially decomposed rock. At first sight it would appear that the freshness of the rock as seen on the Kuala Lumpur–Bentong * road is against its being older than the Mesozoic granite, but there are signs that it has been brecciated and subjected to strong shearing, and any secondary minerals that were formed before those movements may have been reconstituted. Some specimens from Jeram Gading * contain epidote in abundance, and the presence of this mineral, which is characteristic of the igneous rocks older than the granite, is an indication that the quartz-porphyry belongs to the Pahang Volcanic Series, and the numerous boulders of volcanic tuff and breccia, also containing epidote, which can be seen in the stream show that rocks of the series occur in the neighbourhood. In addition, pebbles and boulders of hornblende-augite-schist were seen in the Rivers Seli * and Klang*, and one specimen when examined under the microscope revealed that the schist was originally a porphyritic igneous rock. Similar schists and gneisses in situ bordering the alluvial plain of Kuala Lumpur * are penetrated and altered by the Main Range granite, and the field evidence goes to show that the schistose structure was induced by the earth-movement which took place when the granite was intruded, so it is probable that they were originally rocks of the Pahang Volcanic Series. A single boulder of the quartz-porphyry was found lying on weathered granite at the eighth mile from Kuala Lumpur * on the Rawang road*, and one boulder of the pyroxene-granite-porphyry was found at the foot of Bukit Lanjan*, near Kepong, in Lower Selangor, so it appears that there was a widespread occurrence of the Pahang Volcanic Series in Selangor, but that a great part of it has been denuded since the intrusion of the Main Range granite.

The different types of rocks belonging to the Pahang Volcanic Series are indicated in the following table :—

Series.	Acid.	Intermediate.	Basic.
	70 % SiO_2	60 % SiO_2 50 % SiO_2	40 % SiO_2
Lavas.	Rhyolite. Trachyte.	Andesite.	
Tuffs.	Rhyolite. Andesite-rhyolite.	Andesite.	
Hypabyssal.	Quartz-porphyry and granophyre. Quartz-dolerite.	Porphyry. Dolerite.	Porphyrite.

The rocks mentioned in the table show a decreasing percentage of silica moving from left to right, but as unfortunately it has not been possible to make more than one analysis, the silica percentages in the above table can only be regarded as approximate. It will be seen that no basic volcanic rocks are represented, for it is not known whether the serpentine outcrops which occur in several localities in the Peninsula should be classed as lavas or intrusions, but there is little doubt that the serpentine is a basic member of the Pahang Volcanic Series. If further field-work shows that the serpentine outcrops all occur at the boundary of Raub and Gondwana rocks, as seems to be the case in Negri Sembilan*, it will be clear that the serpentine is an altered lava.

Rhyolites.

Rhyolite lavas have been found in situ at Pulau Chengai and Lubok Plang on the Pahang River, and as derived water-worn boulders embedded in tuff on the railway at Kuala Tekal (Pl. XXIX, Fig. 2) and at the 105th mile, and in the Pahang River at Pulau Guai, Lubok Plang, and Pulau Chengai. In addition there are many rocks which may be altered rhyolites exposed in the valley of Sungei Kechau. The lava in situ at Lubok Plang is in layers, one layer being entirely spherulitic and another showing phenocrysts of felspar and quartz set in a fine-grained crystalline groundmass. There is a good deal of secondary quartz in the rock and a flow-structure is very pronounced in the groundmass, which contains unaltered bands of spherulites, and curved lines marked by opaque secondary material in the remaining finely crystalline part of the groundmass probably indicate that the whole of it was once spherulitic. The rhyolite boulders in the ashy boulder-beds here are very similar to the rock in situ.

Certain boulders in the ashy boulder-beds of Pulau Guai are of rhyolitic lava containing numerous inclusions of shale. For the most part the non-porphyritic portion of the rock is finely crystalline, but here and there the remains of spherulites can be distinguished, and although it has undergone considerable alteration, yet a well-marked flow-structure can still be seen. Probably the groundmass originally was a glass. The quartz phenocrysts are corroded and contain inlets and inclusions of the groundmass. The orthoclase and oligoclase crystals are altered to an opaque brown material and probably also to calcite, for they contain a considerable amount of that mineral, but the whole of the rock is rich in calcite, and perhaps all of it is derived from neighbouring sediments by infiltration. In addition the rock contains small altered crystals of biotite.

Some of the inclusions of the sedimentary rocks are of dark shale, and one slide showed chiastolite crystals in the shale-inclusions, which differ from the rest of the rock in containing no calcite. Other inclusions were of fine-grained volcanic tuff.

This striking rock is found in situ at Pulau Chengai, but none of the boulders of rhyolite embedded in tuff which are found within 100 yards of it were seen to contain shale-inclusions.

The age of the rhyolite of Lubok Plang is Raub period, for it is

associated with Raub rocks, which, however, differ from those of other known localities in including a band of chert.

Trachytes.

No very typical members of this group of lavas are known, but some rocks occur between Jeransong and Jerantut which are related to the trachyte family on the one hand and to the andesitic rocks of Tembeling on the other.

One rock is red-brown in colour with numerous tiny iron-stained patches, and looks very much like a compact quartzite in the hand-specimen. It has S.G. 2·64, and contains very scanty small phenocrysts of felspar up to 1½ mm. in length.

Under the microscope the rock is seen to be holocrystalline and to contain these minerals: orthoclase, oligoclase, calcite, and limonite. The orthoclase forms irregular-shaped prisms about ·03 × ·01 mm., and the oligoclase occurs as prisms with a better shape and about the same size. There is a well-marked flow-structure, and a number of the prisms are slightly bent, owing, probably, to movement while they were still hot and plastic. Large crystals of calcite are common, and there are abundant small areas of calcite scattered throughout the rock, interstitial to the felspar prisms, all of it probably having been derived from neighbouring limestones. Limonite as scattered grains is an important constituent of this rock, whereas another rock from 101½ mile is grey in colour owing to the great amount of pyrites which it contains.

Fairly numerous phenocrysts of felspar are set in a groundmass of felspar prisms, and the whole of the rock presents a cloudy appearance under the microscope, due to the presence of abundant secondary white-mica flakes. The phenocrysts are very much altered, being almost entirely obscured by the mica flakes, but certain clear patches in the mica aggregate consist of albite felspar. Some of the felspar prisms in one specimen were orthoclase, and that is the reason for placing the rock amongst the trachytes (it may be a porphyry); the majority of the felspars, however, are albite and oligoclase. It is possible that the albite is a secondary mineral formed by the alteration of a more basic felspar, but this is not probable, for no remnants of the basic felspar are left.

There are cracks in the rock which are lined with small irregular plates of albite, the centre being occupied by a zeolite, which has a spherical form with fibrous structure, the fibres being arranged to radiate from the centre, and in nearly all cases the centres of the spheres lie on the edge of the felspar which lines the cavity walls. The zeolite fibres under crossed nicols extinguish parallel to their length, and have low double refraction and low refractive index, so it is probably natrolite.

The presence of abundant secondary mica with clear albite and natrolite is fairly strong evidence that the original felspar of this rock was more basic, but, as already mentioned, this is not confirmed by any remains of a more basic felspar.

The pyrites occurs as small grains and never has a good crystal form.

Andesites.

They are dark-purple or green-black rocks containing small phenocrysts of felspar which are visible in the hand-specimen. The S.G. usually varies between 2·68 and 2·76, and the following minerals are usually present: porphyritic felspars, augite, groundmass felspars, a black iron-ore (magnetite or ilmenite), and chlorite.

The felspar phenocrysts as a rule are not more than 1 mm. across, and are strongly zoned and often rounded and corroded by the groundmass. Albite twinning is the rule, and the extinction angle never exceeds 18°, usually being about 10°. The crystals are often very much altered, usually containing abundant mica flakes, but the felspars of the Tembeling andesites often consist of merely a thin shell of felspar, enclosing a pale-green central portion made up of a network of chlorite and felspar. In one such phenocryst the albite twinning could still be distinguished. It can be seen in several specimens without chlorite that the outer shell of the zoned felspars is less altered to mica than is the central zone, and it would appear that the striking chlorite-felspar network, which makes up the greater part of the phenocrysts of the Tembeling andesites, was formed by the mica flakes in the felspar being altered to chlorite. The interference colours of the chlorite are usually blue, and the double refraction is considerably less than that of quartz. The smaller felspar phenocrysts have a sharp outline, in contrast to the larger rounded phenocrysts.

The augite is of a very pale-green colour, occasionally occurring as fairly large well-shaped crystals (Pl. XXIX, Fig. 1), but more often the crystals are small (compared with the felspar phenocrysts) and ill-shaped. Sometimes the augite occurs only as tiny grains interstitial to the felspars of the groundmass, and sometimes none at all can be distinguished in the rock, but this does not mean that augite was not at one time present, for such a rock always contains small areas of chlorite, which probably represent augite grains, distributed throughout the groundmass. The alteration of a phenocryst of augite to chlorite can often be seen in an intermediate stage. No rhombic pyroxene could be seen in any of the specimens, and all the chlorite pseudomorphs after pyroxene seemed to have been formed from monoclinic pyroxene.

The felspars of the groundmass often occur as untwinned lath-shaped crystals measuring about ·06 mm. × ·01 mm. with a low extinction angle, corresponding to albite-oligoclase, and a well-marked flow-structure is often present. They are packed so densely together as to leave no room for a glassy residuum. Iron-ores, probably both magnetite and ilmenite, are usually scattered throughout the groundmass, and often occur as inclusions in the border of the large rounded felspar phenocrysts. Chlorite is abundant, and it is clear that it is usually the result of alteration of augite and felspar.

Epidote is common both as a granular alteration-product of augite and felspar and also in thin veins, and calcite is common as in all the Pahang Volcanic Series rocks. It is probably in many cases the result of infiltration from neighbouring sedimentary rocks.

A Tembeling andesite (No. 3756) was analysed by Mr. J. Shelton, Chemist to Geological Department F.M.S.

Examination under the microscope shows that the greater part of the rock is made up of tiny laths of cloudy oligoclase-andesine with interstitial chlorite. The zoned felspar phenocrysts are largely altered to chlorite, iron-ores are abundant, and small grains of augite occur in the rock. A little epidote is present.

SiO_2	59·02
Al_2O_3	17·23
Fe_2O_3	9·07
MgO	2·42
CaO	4·12
Na_2O	4·20
K_2O	1·68
Loss on ignition	2·64
	100·38

The large amount of iron-ores in the rock is indicated in the analysis, as also is the fact that the felspar is of a soda-lime rather than a lime-soda variety.

A lava rather like this, but containing much more secondary chlorite, from the Benta–Kuantan road, contained numerous amygdules, the small ones being spherical and the larger being elongated along the line of flow.

Pseudomorphs of chlorite and micaceous material after olivine are present in two specimens of rocks from the Tembeling district with S.G. 2·68, and in large fragments of lava from a tuff-deposit near Kuala Lipis, S.G. 2·75. Unfortunately nothing is known of the field relations of these olivine-bearing rocks.

The felspar phenocrysts (acid oligoclase) have rounded corners and have been partially resorbed by the action of the groundmass, and they have a border rich in grains of iron-ores. These phenocrysts of felspar may be as much as 4 or 5 mm. in length, but there is a second generation of smaller felspar phenocrysts which are sharper in outline and show no reaction-border.

The groundmass has suffered alteration, and for the most part consists of an irregular mosaic of felspars and quartz, in which can be distinguished occasional tiny felspars about ·05 mm. in length, and abundant scattered granules of dark material, some, and perhaps all, of which is magnetite.

Another type of andesite (S.G. 2·70) containing abundant large phenocrysts set in the groundmass of microliths, can be seen at several places for a distance of about ¼ mile along the railway, near the 117th mile at Tembeling. There are two sets of phenocrysts, one is 2 or 3 mm. across, with occasional crystals as much as 1 cm. across, and the other set varies between 0·1 mm. and 0·3 mm. in length. Most of the phenocrysts are plagioclase showing albite and microcline twinning, and having an extinction angle corresponding to a composition intermediate between oligoclase and andesine. The large phenocrysts are rounded and show dark reaction-borders. The border is part of the groundmass, differing from the greater part of the groundmass in containing a bigger proportion of a brown

dust pigment (probably iron-ores) which gives nearly all the Tembeling andesites their dark-purple colour. Some big phenocrysts have a border of a different type. The crystal is filled with an opaque dust, possibly kaolinite, and a binary twinning can be distinguished, indicating that this central part is orthoclase felspar, but surrounding the crystal is a narrow band of clearer felspar which is not in crystalline continuity with the remainder of the phenocryst. Needles of ilmenite are scattered about in the crystal, in the clear band more abundantly than elsewhere.

The groundmass is made up of twinned microliths of felspar, which have a low extinction angle, with a certain amount of interstitial quartz, which is probably the result of devitrification of pre-existing glass. There are abundant iron-ores scattered throughout the rock, much of it associated with chlorite, which was formed by the alteration of augite, for pseudomorphs having the form of augite are the rule. Apatite is a common accessory, and an irregular-shaped grain of a mineral like sphene was seen in the rock.

Andesites are found interstratified with Raub and Gondwana rocks both as lavas and tuffs, and it appears that the andesite phase was predominant during the whole period of the Pahang Volcanic Series.

Quartz-porphyry and Granophyre.

Between the 101st and 102nd mile on the Pahang Railway there is a considerable development of intrusive rocks consisting of quartz-porphyry and granophyre. They probably belong to the same period of eruption as the rhyolites of Lubok Plang, a few miles to the east, and contributed to the formation of certain fragmental deposits in the neighbourhood by adding more acid material to what would otherwise have been andesite tuffs and breccia. The rocks are associated with intrusions of a more basic composition, both dolerite and porphyrite.

About 10 miles further north there are extensive exposures of granophyre both in the river and the railway cuttings, and there is a strong development of quartz-porphyry near the railway near Sibah and Lanna. Other exposures occur along the Benta–Kuantan road and in the valley of the Kechau River.

Quartz-porphyry.

The rock consists of felspar phenocrysts, quartz phenocrysts, chlorite, and iron-ores probably formed by the alteration of augite, apatite, a fine-grained holocrystalline quartz-felspar groundmass, and secondary minerals. Its specific gravity varies between 2·57 and 2·75.

The felspar phenocrysts are most commonly of a plagioclase with composition between oligoclase and andesine, but orthoclase is usually present in less quantity. Occasionally there are two sizes of felspar phenocrysts, all being altered, either to kaolin or to a micaceous mineral. The quartz crystals are practically always corroded by the groundmass. Augite is rarely seen in the quartz-porphyries, but they usually contain pseudomorphs of chlorite associated with magnetite, whose form resembles basal sections of augite, and one

rock contains light-brown augite with lamellar twinning. Apatite is a very constant accessory and is often very abundant.

The most common secondary minerals are calcite derived in part from neighbouring sedimentary rocks and epidote. Some of the calcite is an alteration-product of the felspar. A dark-green fibrous mica has been noticed occasionally. The groundmass is usually a holocrystalline fine-grained granitic mosaic of quartz and felspar in which sometimes microlites of felspar can be detected, and occasionally a microspherulitic structure is present, while some quartz-porphyries have a granophyric groundmass, and thus form a link with the granophyres next to be described.

Granophyre.

The granophyres are exposed in the Pahang River for a distance of 2 miles upstream from Pulau Guai, 2 or 3 miles above 111th mile on the railway, and with the quartz-porphyries of the 101st mile on the railway. The exposures in river and railway all occur on a line of strike running about N. 10° W. by S. 10° E., and the intrusion may be quite narrow, but if continuous its length is over 10 miles.

It is usually white in colour, and all the specimens that have been collected have a specific gravity of about 2·60. Under the microscope, particularly between crossed nicols, these rocks present a beautiful appearance. Quartz phenocrysts and phenocrysts of orthoclase and oligoclase make up a large portion of the rock. Biotite mica is sometimes present, and apatite and pyrites are constant accessories. Of secondary minerals calcite is the most common, and one specimen has felspar phenocrysts containing abundant flakes of chlorite.

A lava with traces of granophyric structure occurs just below the mouth of the River Chika, interstratified with Gondwana rocks, but near the boundary of the outcrop. It may be of the same period of eruption as the granophyre intrusions, which would therefore be assigned to the period of deposition of the oldest Gondwana rocks, but the fact that tuffs which are interstratified with Raub rocks contain granophyre fragments shows that the period of intrusion of some of the granophyre was Raub.

Reference has already been made to the boulders of dark-coloured quartz-porphyry which lie scattered about on the Main Granite Range. They occur at the Ginting Sempak* road at the 11¼, 17th, 20½, 22½ miles, and at several places going down the Pahang side of the pass, also on the way to Ginting Bidei* from Klang Gate*, both as boulders and in situ, and as a single boulder near the 8th mile Rawang road*.

In the hand-specimen white phenocrysts of felspar and quartz can readily be distinguished, the dark-purple or black groundmass having a compact homogeneous appearance, and under the microscope it is seen that the felspar varies from oligoclase to labradorite and that it is often strongly zoned, the kernel being more basic than the exterior zones. The felspar and quartz are angular in outline and sometimes rounded. A little uralitized augite is an occasional constituent, suggesting a connexion with the granite-porphyry next to be described. Well-shaped crystals of biotite are common, often very

much altered to chlorite with the separation of iron-ores, and very often they have been bent by shearing movements which have imparted a flow-structure to the groundmass, these same shearing movements in all probability being responsible for the angularity of the quartz and felspar crystals. The groundmass, in those specimens which have not been sheared, is that typical of a quartz-porphyry or rhyolite, and occasionally it is made up of microspherulitic structures. Some specimens much resemble tuffs, but no fragments of lava have been observed in them, and their tuff-like appearance is probably due to brecciation by shearing movements.

From the uniformity in the appearance of quartz-porphyry both in the hand-specimen and under the microscope, when examined as boulders in the different localities above described and in situ, it seems to be clear that the rock is an intrusion and not a lava, and this view is supported by the total absence of any appearance of stratification or variation when traced through the 100 feet or so of thickness of rock which is exposed at Jeram Gading*. It was not possible to go more than ¼ mile upstream from the point in the River Seli* where the quartz-porphyry was first encountered in situ, and the extent of the outcrop is unknown, but from the rocks exposed downstream it appears that the quartz-porphyry was intruded into cherts, grits, and quartzites, and is therefore of a later age than the other intrusions of the Pahang Volcanic Series.

The granite-porphyry also referred to in the account of the distribution of the Pahang Volcanic Series is not definitely proved to belong to the series, but it is usually associated with the purple quartz-porphyry, and its occurrence at Ginting Sempak* and Ginting Bidei* suggests that it was lifted to form the caps of those hills by the intrusion of the granite, and that it is therefore older than the granite.

The hand-specimen is always green in colour, and is apparently composed of a mosaic of quartz and felspar of uniform grain with also abundant flakes of biotite, but under the microscope the rock is seen to be markedly porphyritic. The phenocrysts are felspar, varying from oligoclase to labradorite, quartz, biotite, both rhombic and monoclinic pyroxene, with smaller quantities of black iron-ores, apatite, zircon, and blue tourmaline, and the groundmass is a perfectly clear mosaic of quartz and felspar (oligoclase to labradorite), which has sometimes the appearance of micropegmatite.

The phenocrysts of felspar and quartz usually have an irregular form and are encroached upon by the groundmass. The form of the zoning of some of the felspar phenocrysts shows that, after they were formed, they were reduced to a mere fraction of their original dimensions, and a phenocryst was noted with one end altered to an aggregate of mica flakes, the aggregate extending on one side much beyond the present boundary of the felspar crystal and yet containing no small blebs of quartz corresponding with those of the groundmass. It is clear that the phenocrysts have been resorbed by the groundmass, but after consolidation, the action being probably the result of shearing movements. The biotite is deeply pleochroic and is of a deep brown colour. Some of the crystals are bent, like the biotite

crystals in the quartz-porphyry last described, but some of it is not distorted in any way, and from this, and the very irregular outline, it is concluded that some of the biotite is secondary.

The pyroxene is in colourless, poorly shaped crystals, and much of it is certainly a monoclinic variety, but some crystals showing longitudinal cleavage extinguish straight between crossed nicols and are therefore a rhombic pyroxene. The interference colours in slides where quartz sometimes gives pale yellows vary between wide limits, for both the monoclinic and the rhombic pyroxene, from grey of the first order (like quartz) to brilliant blues and greens of the first order. The pyroxenes are altered to two distinct products, one appearing in section as a thin strip surrounding the crystals, made up of small fibres of green mica, set diametrically across the strip, and thin bands having this composition sometimes penetrate the augite and the quartz and felspar too. The other alteration-product is a pale-brown chlorite of mica in plates and flakes which replace the greater part of the crystal. In some specimens some of the pyroxene crystals have been completely replaced by the alteration-product, while in others the pyroxene is left quite fresh.

From the specimens examined it appears that since consolidation the rock has been affected by considerable earth movement resulting in a complete reconstitution of the groundmass, the partial brecciation of the crystals, and the formation of biotite.

It is probable that a trip further upstream beyond Jeram Gading* will show this granite-porphyry in situ, for boulders of pebbles of the rock are very common there. From the description of the rock it is clearly a metamorphosed igneous rock—the granulitic groundmass, the brecciation of the crystals, the puckering of the original altered biotite, and the interstitial nature of the other rich brown biotite all indicate that it has been formed from an igneous rock by intense shearing movements. Although many of the boulders of the rock in the River Seli* and on the flanks of the Ginting Bidei* hill are many yards across, yet no exposures clearly in situ were seen.

Occasionally small patches of a finer-grained material are enclosed in the rock, which when examined under the microscope are found to differ from the rest of the granite-porphyry only in their finer grain. Apart from these few patches, the rock is remarkably constant in grain as well as in composition, and considering that it is known to occur intermittently as large boulders over an area of 100 square miles this is perhaps one of its most striking features.

Boulders of schist, made up of hornblende, augite, and felspar, were collected from the same locality, and one less metamorphosed specimen contains altered fragments which reveal that the original rock, from which the schist was formed, was a porphyritic igneous rock. The three minerals are confined more or less to individual bands, with a thickness sometimes reaching $\frac{1}{4}$ inch. The hornblende is a green pleochroic fibrous variety, and the augite is light-brown in colour, occurring like the felspar in granules. The felspar is orthoclase. The specimen mentioned above, which has been less highly metamorphosed, does not show a foliated structure. It is made up of sheared oligoclase-andesine felspars set in a fine-grained

groundmass which contains scattered fibres of hornblende and large patches of augite and secondary quartz. A similar rock occurs in situ in the belt of schists fringing the Kuala Lumpur plain, associated with gneisses made up for the most part of secondary micas and quartz in which remain "eyes" of felspar or quartz phenocrysts that have resisted shearing. It is not proposed to do more than mention these rocks, though they are certainly older than the granite and are probably members of the Pahang Volcanic Series.

Porphyrite.

Near the 101st mile on the Pahang railway there is a good exposure of an intrusive rock which is markedly porphyritic, no quartz however occurring as phenocrysts. In one exposure the rock has a pink-white colour, with light-green phenocrysts of felspar ranging up to 1·5 cm. in length, and in a neighbouring exposure the rock is grey in colour with white phenocrysts. The specific gravity of the first rock is 2·55, whilst that of the second is 2·62—the increase probably being solely due to the large amount of iron-pyrites which is present in the grey rock.

The phenocrysts are of basic oligoclase or andesine with a very ragged outline, and lie in a granitic groundmass of oligoclase-andesine, felspar, and quartz.

The groundmass consists of a fairly cross-grained mosaic of badly formed crystals of plagioclase and possibly too of orthoclase, of length averaging 0·5 mm., with some finer-grained mosaic. Quartz is present, some of it perhaps being primary, and there is abundant secondary mica with also a little chlorite.

Dolerites.

Intrusions of dolerite were seen in only two cuttings of the Pahang Railway, namely at the 101st mile, where the rock is a fine-grained quartz-dolerite like a lava, and at the 104½ mile, while none were seen on the Pahang River between Kuala Lipis and Mengkarak. However, they are known to occur at several places along the Benta–Kuantan road, in the zone of the Pahang Volcanic Series.

At the 101st mile the quartz-dolerite is in contact with quartz-porphyry. The relations of the two rocks were not determined, but it was clear that the quartz-porphyry was intruded into interbedded ashes and shales.

At the 104½ mile the dolerite is associated with shales, tuffs, and andesitic lava, and some of the tuffs near here contain water-worn boulders of volcanic rocks which will be described later. The dolerite at the 104½ mile is considerably altered, the hand-specimen being a dark-green rock containing occasional phenocrysts of augite up to ½ cm. or more in length with prisms of altered plagioclase, some of which has extinction angle corresponding to oligoclase-andesine. The felspars have ophitic structure with regard to a green mineral which has been formed as a result of the alteration of augite, and there are some fragments of augite still remaining. A little of the green mineral is chlorite, but most of it is an amphibole, some of it of a fibrous habit, and some of it replacing the augite crystal for crystal. There is a considerable quantity of ilmenite present.

The rock at 101st mile differs in that it is fine-grained; it contains interstitial quartz, and all the augite has been altered to a chloritic mineral. It contains a good deal of calcite, possibly derived from the decomposition of the felspars, which enclose numerous white mica flakes, and it also contains abundant ilmenite.

There are a number of dolerites known in the Peninsula which are of a considerably later period of eruption. In some cases the intrusion occurs in quartzite, and is therefore probably of later age than the Gondwana Series, in other cases still the dolerite dykes penetrate the Mesozoic granite, and the latter, like many acid intrusive rocks which penetrate the granite, are not included in the Pahang Volcanic Series.

There are other intrusions of doubtful age where the field evidence is not sufficient to assign them definitely to one of the two groups. The dolerite of Batu Bersawah * gold-mine in Negri Sembilan, which is intrusive into Raub shales and limestones, is veined with calcite and has been much sheared, so there is no doubt that it belongs to an early period of eruption, for it is probable that the only extensive shearing movements in this district took place at the time of the intrusion of the Mesozoic granite. The rock is much weathered, the ferromagnesian mineral being completely altered, and chlorite, pyrite, and ilmenite partly changed to leucoxene are abundant.

A rock with ophitic structure occurs in two localities along the road * from Kuala Lumpur to Bentong as a band about two yards wide in phyllites at the 17½ mile, and in a high cutting 250 yards short of the 21st mile as a band in contact with sheared chert and within a few yards of a large development of felspathic grits. It was seen by Mr. Scrivenor in 1907 as lenses between chert bands exposed in the road-cuttings which were newly made at that time, suggesting that the rock is a pillow-lava. Mr. Scrivenor collected chert specimens from near the 17th mile also in 1907, but weathering has since destroyed the freshness of the exposures.

The rock at the 17½ mile is dark-grey and finely crystalline, made up of good-shaped narrow prisms of felspar about ¼ mm. long, with a low extinction angle corresponding to oligoclase, and poorly shaped crystals of hornblende of the same size. There is nearly as much hornblende as there is felspar, and it is noteworthy that the felspars have a better crystal shape than the hornblende. Occasionally there is a larger and broader phenocryst of oligoclase with length of nearly 2 mm. There is a little apatite and a little quartz as interstitial grains. Abundant cubes and grains of pyrites are disseminated throughout the rock, probably all of it secondary, and veins and streaks made up of fibrous serpentine or chlorite, quartz, and an opaque fine-grained dust also make up a considerable proportion of the rock.

Many specimens of the rock near the 21st mile have been examined, very similar in texture and colour to the above in the hand-specimen. Felspar prisms, like those described above, make up the same proportion of the rock, but there is a total absence of hornblende, the spaces intervening between felspar prisms being filled with serpentine or chlorite, quartz, ilmenite skeletons, and calcite. There are no porphyritic felspars and no apatite was

observed. Some pyrites is present. Veins of fibrous serpentine or chlorite penetrate the rock and there are also veins of calcite.

The evidence is all in favour of the volcanic rocks at the 17½ and 21st miles being identical, the one near the 21st mile having suffered considerable alteration. The felspars in both rocks are partially obscured by an opaque dust, but the extinction angles can be measured in many cases, and there is no doubt that these correspond to oligoclase. There is no sign that the felspar was originally a more basic variety that has undergone albitization, but the association of the volcanic rock with chert at once suggests that the latter owed its origin to the fact that the sea-water was highly charged with silica derived from pneumatolytic gases which were given off by the volcanic rocks. These same gases may have attacked the basic felspar of the volcanic rocks, turning it into a more alkaline variety, and at the same time releasing some of the calcium as calcium carbonate. Under these conditions radiolarian organisms flourished and their siliceous remains dropped to the sea-bottom and there formed beds of chert. However, no proof has yet been obtained that the felspar of the rocks was originally more basic.

Greenstones.

In early reports[1] certain "greenstones" were often referred to which are probably all members of the Pahang Volcanic Series, in which chlorite, epidote, and calcite have been developed by weathering. It is sometimes difficult to distinguish whether they are tuffs, lavas, or intrusive rocks, and probably all three occur, but their relationship with the series as a whole is easily recognized.

Serpentine.

Serpentine occurs in Perak*, Pahang, and also in Negri Sembilan*, but its relation to the Pahang Volcanic Series is not yet known, though, as it is known to be strongly sheared in Pahang and in one of the Negri Sembilan* outcrops, it is probably of pre-granitic age. An outcrop at Bersiah* in Upper Perak* contains olivine, but the indications are that the serpentine of all the other outcrops was formed by the alteration of amphibole. The four known outcrops in Negri Sembilan* seem to occur at the boundary of Raub and Gondwana rocks, but as this fact has not been definitely proved it is useless to theorize about its significance. There is little doubt that the serpentine is an altered lava or intrusion of Pahang Volcanic Series age.[2]

EXPLANATION OF PLATES XXIX AND XXX.

Fig. Plate XXIX.

1. Augite-andesite, 41st mile, Benta–Kuantan road. × 30 diam.
2. Olivine-andesite, Kuala Teh, Pahang Railway. × 30 diam.
3. Quartz-porphyry with flow-structure, Ginting-Sempak. × 25 diam.
4. Andesite-rhyolite breccia, 47th mile, Benta–Kuantan road. × 25 diam.

(*Photographs by J. B. Scrivenor.*)

Plate XXX.

Map[3] of Pahang Volcanic Series, Federated Malay States.

[1] These are alluded to in the Ulu Pahang Memoir, p. 41.

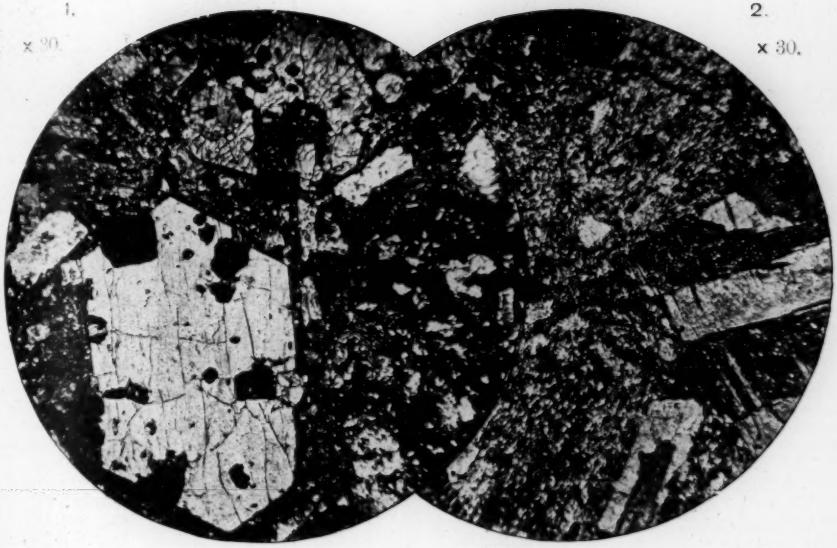
[2] This article is published by permission of the Geologist, F.M.S.

[3] The Map (Plate XXX) will appear with the second part of this paper in the November Number.

(*To be concluded in our next Number.*)

1.
x 20.

2.
x 30.



3.
x 25.

4.
x 25.

J. B. Scrivenor, photo.

ROCK-SECTIONS, PAHANG VOLCANIC SERIES, F. M. STATES.

IV.—A System of Petrography.

By S. J. Shand, D.Sc., F.G.S., University of Stellenbosch, South Africa.

THE recent paper by A. Holmes on "A Mineralogical Classification of Igneous Rocks" [1] is an attempt to settle a matter which English-speaking petrologists ought to have tackled long ago. There seems, however, to be a disposition, on the part of British geologists especially, to leave the matter alone in the fond belief that some "natural" system of classification will presently be revealed to us whereby all our taxonomic doubts and difficulties will be dispelled. Nothing can be more unreasonable. The philosophic treatment of a subject must follow, not precede, the preparatory work of discriminating, sorting, and docketing; and the sharper the discrimination, the more thorough and orderly the sorting and docketing, the easier to make the philosophic digest. Hitherto petrographers have not discriminated well; we have not done our sorting in a methodical way; we have tied on labels in the most haphazard fashion; our house is in a state of dreadful confusion. It is true that through all the disorder we have caught fascinating glimpses of regularities and relationships; of connexion between this and that; but the deplorable fact appears that we are unable to test or verify any hypothesis, or to take a single confident step towards the philosophic treatment of our subject, until we put our house in order. We have got to do our sorting and docketing all over again, and do it methodically, and then only can we begin to look for the philosophy of the matter.

I have already taken in this journal what I consider to be the first step in the process of bringing order out of confusion—I refer to the separation of five prime divisions of igneous rocks on the basis of the degree of saturation of their constituent minerals.[2] I should in the near future have tried to indicate some further steps in the same direction, but I wished to present a complete scheme, with illustrative examples, and this, with the imperfect facilities of a Colonial university, has taken much time. Now that Mr. Holmes has broached the question, however, I think it ought not to be allowed to drop until some understanding is reached, and I wish therefore to submit an alternative system in very brief outline.

Holmes adopts my five saturation classes as the basis of his arrangement, and then effects a first subdivision within each class by means of a cross-classification in which the orthoclase-albite ratio is put against the albite-anorthite ratio. In arriving at the former of these ratios he proposes to calculate the felspathoids, micas, and analcite into their equivalent amounts of orthoclase and albite. Following upon this he makes the historic separation of plutonic rocks from dyke-rocks and lavas; and to establish still smaller subdivisions he suggests (but does not elaborate in his paper) the employment of the colour ratio (felsic-mafic ratio) and the texture, in that order.

[1] Geol. Mag., March, 1917, p. 115.

[2] Geol. Mag., November, 1913, p. 508; November, 1914, p. 485; August, 1915, p. 339.

In the classification adopted by Iddings[1] there are also five primary groups, characterized respectively by (1) quartz in excess, (2) quartz and felspar, (3) felspar with little or no quartz, (4) felspar and felspathoid, (5) felspathoid without felspar. Within each of these groups Iddings employs a cross-classification in which the colour ratio (expressed simply by the terms leucocratic and melanocratic) is put against the ratio of alkali- to lime-bearing felspars. The next subdivision is based on crystallinity, only two groups, phanerocrystalline and aphanitic, being recognized; and further splitting is effected on grounds of texture, or preponderance of a particular mineral, or for other trivial reasons.

Now I am with Holmes in adopting the degree of saturation as the basis of classification; with Iddings in desiring to give increased prominence to the colour ratio; with Iddings also in preferring a twofold to a threefold division with regard to crystallinity; and with both of them in recognizing the necessity of yielding to the old-established practice of distinguishing potassic from sodic and calcic rocks on the basis of the felspars which they contain. I differ from both Holmes and Iddings regarding the treatment of felspathoids and in certain other minor matters.

I propose to apply the various taxonomic factors in the following order:—

1. Degree of saturation, giving five divisions.
2. The double ratio of Or-Ab-An, giving about eight families within each division.
3. The colour ratio,[2] giving from two to ten, but preferably four groups in each family.
4. Crystallinity, giving two sub-groups within each group.
5. Ratios of specific minerals or groups of minerals, giving the types to which "specific" names will be attached.
6. Trivial characters of mineralogy and texture, giving varieties.

I shall discuss the application of these factors very briefly.

1. Regarding the employment of the degree of saturation as the basis of the system I have nothing to add to what I have already written. It furnishes five sharply distinguished divisions, as follows:—

(1) Oversaturated rocks [O].
(2) Saturated rocks [S].
(3) Undersaturated rocks.
  (*a*) Dyad and triad metals unsaturated [u].
  (*b*) Monad metals unsaturated [U].
  (*c*) Both monads and dyads unsaturated [W].

2. The distinction of potassic from sodipotassic and sodic rocks, judged by the ratio of orthoclase to albite, is deeply ingrained in petrography. Iddings has tried to make the distinction quantitative by introducing the limiting ratios of 5 : 3 and 3 : 5, or 37·5 per cent

[1] *Igneous Rocks*, vol. i, 1910.
[2] *Journ. Geol.*, 1916, p. 400.

and 62·5 per cent. It has to be recognized that strict application of these limits is difficult in some cases, as for example where the felspar is soda-orthoclase or microperthite, but we ought not to be contented with any lower degree of precision than that which these three subdivisions afford. To be strictly logical we ought to use the Or-Ab ratio only for leucocratic rocks, employing a lime-magnesia-iron ratio in the same way for melanocratic rocks, but this would involve a great departure from existing nomenclature and is better left alone at present.

A new point is introduced here by Holmes' proposal to calculate felspathoids and micas into their equivalents of orthoclase and albite for the purpose of classification. I am unable to accept this proposal, partly because it takes us away from the actual composition of the rock and partly because in many cases it must be impracticable and its results misleading. That this is not too severe a view the following considerations will, I think, show:—

(1) Natural leucite always contains a variable quantity of soda.

(2) Natural nephelite, as recently shown by Bowen,[1] holds from 10 to 35 per cent of a plagioclase molecule and from 15 to 30 per cent of kaliophilite.

(3) Rock-forming micas may hold lithia and soda as well as potash, and alumina may be replaced by iron.

(4) The proportion of a mica is extremely difficult to estimate accurately, whether geometrical methods or heavy liquids are employed. The scales tear away in making sections, and they do not give a clean separation with liquids.

I cannot see how the first three of these difficulties can be overcome unless every mineral is analysed as well as weighed.

It is simpler, and it avoids all possibility of misrepresentation, to use the ratio of

(orthoclase + leucite) : (albite + nephelite + sodalite, etc.)

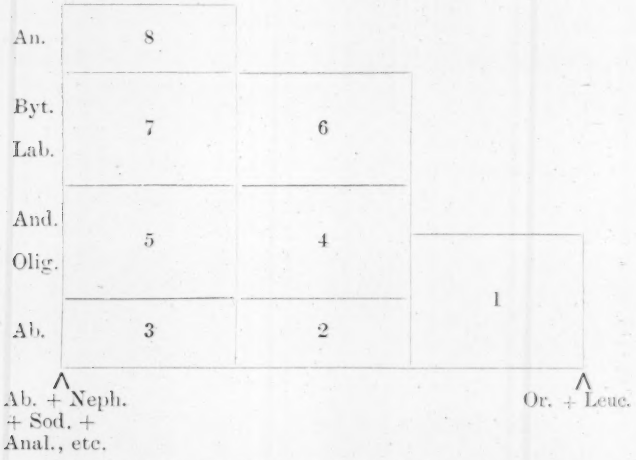
without any modification, and with the usual limiting values of $\frac{1}{8}$ and $\frac{7}{8}$. The difference between this procedure and that of Holmes is important. Holmes aims at an expression of the ratio of potash to soda; but for the reasons already advanced his statement will rarely be quite true, and may be seriously untrue, unless each mineral is analysed separately. I, on the other hand, am content to state the ratio of the essentially potassic minerals orthoclase and leucite (with whatever dissolved molecules they may hold) to the essentially sodic minerals albite, nepheline, sodalite, etc. (with their dissolved molecules). Holmes uses an unreliable norm: I prefer the plain truthfulness of the mode.

3. As regards the albite-anorthite ratio which is to be crossed with the above, custom has drawn loose lines of division between albite and oligoclase and between andesine and labradorite. Holmes makes the matter more precise by drawing the lines at 15 and 50 per cent of anorthite. Here again, while recognizing the difficulty of adhering strictly to these limits (as, for example, when the

[1] *Amer. Journ. Sci.*, February, 1917.

felspars are zonally built), I am for aiming at the highest attainable precision. For completeness we ought to make another boundary at 85 per cent of anorthite, for rocks rich in anorthite deserve special recognition just as much as the albitic ones. This is not a new line of division, for it has been customary in the past to distinguish between gabbro and eucrite.

Putting now the Or-Ab ratio against the Ab-An ratio, we establish a number—which is theoretically twelve but practically only eight—of families within each of our saturation divisions. The general scheme will be the same for each division, as follows:—



In order to indicate the contents of each of these family-compartments I shall confine my attention for the present to the holocrystalline rocks. Divisions are indicated by means of the letters O, S, u, U, and W, and the "family" names employed in each division show by means of a prefix or suffix the division to which they belong. Thus all names of saturated or oversaturated rocks end in *-ite*; those of U-rocks in *-oid*[1]; names of u-rocks may carry either the prefix *sub-* or the suffix *-ole*; and for W-rocks the prefix *sub-* will be used in conjunction with the suffix *-oid*. Where a name is put in brackets it is to suggest that a new name is required.

O 1, granite; 2, ekerite; 3, (albite-granite); 4, granodiorite; 5, tonalite; 6, granodolerite; 7, (quartz-gabbro); 8, (?).

S 1, syenite; 2, laurvikite; 3, (albite-syenite); 4, monzonite; 5, diorite; 6, (orthoclase-gabbro); 7, gabbro; 8, eucrite.

u 1, subsyenite; 2, sublaurvikite; 3, (?); 4, submonzonite; 5, subdiorite; 6, (?); 7, subgabbro; 8, subeucrite.

U 1, (syenoid); 2, laurvikoid; 3, (foyaoid); 4, monzonoid; 5, essexoid; 6, (?); 7, theraloid; 8, eucroid. (*Alternatively*, U 1, 2, 3, syenoid; 4, 5, dioroid; 6, 7, 8, gabbroid.)

W 1, subsyenoid; 2, sublaurvikoid; 3, (subfoyaoid); 4, submonzonoid; 5, subessexoid; 6, (?); 7, subtheraloid; 8, subeucroid. (*Alternatively*, W 1, 2, 3, subsyenoid; 4, 5, subdioroid; 6, 7, 8, subgabbroid.)

[1] Trans. Geol. Soc. Edin., 1910, p. 376.

4. We have next to attend to the colour-ratio—that is, the ratio of the heavy, mostly dark-coloured minerals to the light, mostly pale-coloured minerals. The really important point about them is of course their density, but the colour is a convenient mark of it. I have already proposed the use of a set of prefixes to indicate this character.[1] I would go further than this, and actually give different names to rocks with conspicuously different values of the colour-ratio. This is already done sometimes, as in the following cases:—

orthoclasite → syenite → shonkinite → perknite
anorthosite → gabbro → (picrite) → pyroxenite, etc.
alaskite → granite →

To make such a distinction quantitative, it would accord fairly with existing practice if we fixed the boundaries at 3, 50, and 97 per cent of heavy minerals. In the oversaturated division it is obvious that the melanic end-member of each family would be a quartz-perknite. In the S and U divisions it would be a pyroxenite or hornblendite. In the u and W divisions the corresponding end-member would be a peridotite or cromaltite.[2] All the varietal names required for the more minute description of these are already in existence. For the leucocratic end-members too it will rarely be necessary to find new names, since nearly all cases are already covered by such names as orthoclasite, albitite, oligoclasite, anorthosite. It is mainly for the third group, containing from 50 to 97 per cent of heavy minerals, that new names analogous to shonkinite will be required. Owing to the similarity of the end products, the total number of distinct groups will not be 8×4, but practically about 20 in each division. The four groups in each family may be distinguished by the letters L, l, m, and M where suitable names are not at present in existence.

5. As regards crystallinity, I have a decided preference for the *two* groups of Zirkel (and Iddings) as opposed to the three groups of Rosenbusch (and Holmes). As everybody knows, there is no special set of characters which one can postulate of a so-called dyke rock—not even that it occurs in a dyke. Some dyke rocks have all the characters of plutonics, others all those of lavas. There are in fact only two sets of cooling conditions which produce really significant differences in the characters of the rocks formed under them; these conditions are slow cooling with a sufficiency of fluxes and rapid cooling with diminished content of fluxes: that is, plutonic and effusive conditions, giving rise to phanerocrystalline and aphanitic rocks respectively. If it is desired to express the actual manner of occurrence of a rock mass, it can be done by means of a prefix attached to the name, as dyke-granite, dyke-rhyolite, and so on. A tinguaite I would describe as a dyke-phonolite, a grorudite as a dyke-ekerite or microekerite, a vogesite as a dyke-shonkinite, a hedrumite as a micronordmarkite, etc. In this way a great number of superfluous names might be eliminated and others reduced in value from group names to mere varietal names.

[1] *Journ. Geol.*, 1916, p. 400.
[2] Melanite-pyroxenite: Trans. Geol. Soc. Edin., 1910, p. 376

The names of the *aphanitic* subfamilies in this system ought of course to be drawn from existing names of lavas, just as those of the phanerocrystalline rocks have been derived from existing names of plutonic rocks, and the same set of prefixes and suffixes may be used to signify the degree of saturation, thus: andesite, subandesite; latite, sublatite, latoid, sublatoid; and so on. A certain amount of redefinition of names will be necessitated, and a number of new names will be required. It is not proposed to coin these in advance: it is better that the supply should wait upon the demand. In the meantime it is always possible to describe any rock by means of its co-ordinates in the system, thus: O 3 L 2; S 7 1 1; u M 1, etc.

6. With five divisions, about twenty effective groups in each division, and two subgroups within each group, we have already distributed all known igneous rocks into about 200 compartments. Within each of these compartments there is still room for considerable variation as regards both the minerals themselves and their proportions. A further use of the colour-ratio prefixes, l_5 to l_9 and m_5 to m_9, makes it possible to describe variations in quantity of light and dark minerals. In the same way we may express different degrees of oversaturation by means of prefixes, O_1, O_2, O_3, etc. It will still be necessary to discriminate between different mineral associations. Compartment U 2, for example, holds both leucite-albite rocks and nepheline-orthoclase rocks, and these will certainly require different "specific" names. Again, in the u division we find rocks with unsaturated magnesium and others with unsaturated calcium; and in W the melilite rocks (for melilite holds soda as well as lime and magnesia) form a distinct facies. It is therefore to be expected that from 300 to 500 "specific" names will be required in all. These should be supplied, of course, partly by the readjustment of existing names and partly by the coining of new ones as the need arises. Still further subdivision is possible on a basis of texture; but it is the writer's opinion that differences of texture, other than the one fundamental difference already considered, should be expressed by prefixes or descriptive adjectives, not by the coining of new names.

It will be noticed that no place has been found in this system for the order of crystallization. This is one respect in which it is to be hoped that the system may in future suffer modification. In the meantime the discrepancies between theory and observation are so great that it would only be misleading to give to this factor any place in systematic petrography.

In conclusion, let me say that I do not claim for the system elaborated above that it is either a "natural classification" or a final one, or that it will enable one to dispense with chemical analysis. It is nothing more than a system of indexing, based as far as possible on *significant* mineralogical data treated quantitatively. It lays down lines along which the naming of rocks should proceed, and fixes sharp boundaries which no rock-name should transgress if it is to be more than a mere sack-name. The coining of unacceptable new names is largely avoided by the use of simple prefixes and suffixes, and where existing names have been used their connotation has been

narrowed but not radically altered. A thorough reformation of petrographic system is urgently called for, and it is felt that the scheme now presented affords a great increase of precision and significance at the cost of the smallest possible rearrangement of ideas. I do not wish to compare this system more closely than I have already done with those of Iddings and Holmes, but it is my hope that English-speaking petrologists will awaken to the necessity of themselves testing these and any other propositions that may be forthcoming, and of coming to some agreement regarding the exact meaning of the terms they use. There is room for wide differences of opinion, but "the dust of controversy—what is it but the falsehood flying off?"

REVIEWS.

I.—A Gigantic Eocene Bird.

The Skeleton of *Diatryma*, a Gigantic Bird from the Lower Eocene of Wyoming. By W. D. Matthew and Walter Granger. Bull. Amer. Mus. Nat. Hist., vol. xxxvii, pp. 307–26, pls. xx–xxxiii, 1917.

So long ago as 1874 Professor Cope gave an account of some fragmentary remains of a very large bird from the Lower Eocene of New Mexico, referring it to a new genus and species under the name *Diatryma gigantea*. Since that time a few additional fragments have been described by various writers, but it was not until last year that the discovery of the greater part of a skeleton in the Bighorn basin of Wyoming made it possible to get any clear idea of the structure of this remarkable creature. This specimen has now been described and figured and its affinities discussed by Messrs. Matthew and Granger in the memoir referred to above.

Diatryma is now shown to have been a ground bird of great size, standing some 7 feet in height and possessing a relatively very large head and vestigial wings. It was not a "Ratite" in the usual sense of the word, but like *Phororhacos*, to which it has much superficial resemblance, was a highly modified Carinate, most of its peculiarities resulting from its loss of the power of flight. The skull, as in *Phororhacos*, is of extraordinary size, measuring about 17 inches in length and being largely made up of a great compressed beak 9 inches long by 6½ high. The tip of the beak is not decurved as in *Phororhacos*, and the small sharply defined nostrils are situated rather nearer the ventral than the dorsal border of the beak and some 2 inches in front of the orbit, which seems to have been incomplete below. The supra-temporal fenestra is closed below by the union of the postorbital with the squamosal. The quadrate has a single transversely expanded head with two imperfectly separated facets for articulation with the squamosal. The jugal is stout and its anterior end unites with the maxilla much above its ventral border. The vertebræ are short but massive, especially in the cervical region. The ribs are wide and thin, with little or no trace of uncinate

processes. The sternum is unknown. The shoulder-girdle is more like that of a Ratite than that of a normal Carinate, the coracoid and scapula being almost in the same straight line instead of making a sharp angle with one another; the coracoid is short and broad. The humerus has undergone great reduction and is in much the same condition as in the Cassowaries; the structure of the rest of the wing is unknown. The pelvis is remarkably short in front of the acetabulum, but is long and wide posteriorly; the ilium and ischium are co-ossified, and the pubis, which is in contact with the ischium, unites with it for a short distance. This pelvis is not at all like that of a Ratite bird, but is said to resemble that of *Cariama*. The bones of the hind limb are completely adapted for a pedestrian gait, and probably the adaptive characters have completely masked any that might throw light on the relationship to less specialized forms.

The authors discuss the possible relationship of *Diatryma* to other birds. They dismiss, probably quite rightly, the idea of any near affinity with the later *Phororhacos*, but at the same time suggest a relationship with *Cariama*, apparently on rather slender grounds. They conclude that "probably *Phororhacos* is a derivative of some extinct Eocene type of normal adaptation allied to the Eocene ancestors of *Cariama*, while *Diatryma* would be a derivative of normal Cretaceous Euornithes, allied perhaps more closely to the ancestral line of *Cariama*".

From inspection of the photographs alone, it is perhaps rash to offer any suggestions, but several points in the structure of the skull seem worthy of notice. From the figure it appears that there was probably a well-developed fronto-nasal hinge such as is especially well developed in the Parrots; the supposition that such a joint existed seems to be supported by the condylar form of articulation of the pterygoid and palatine. Again, the closing of the supratemporal fossa below occurs in many Parrots, and small, sharply defined narial openings also occur in some members of that group, as the authors point out. The form of the jugal and the manner of its union with the maxilla is also parrot-like. On the other hand, in Parrots the orbit is usually closed below, while in *Diatryma* it remains open, at least apparently so. A simple-headed quadrate, very similar to that of *Diatryma*, occurs in *Stringops*, which is regarded by Fürbringer[1] as the most primitive type of Parrot, although its primitive characters are obscured by later specializations, while the group, as a whole, is considered by the same writer as a very ancient one. Of course, the form of the bones of the hind limb of *Diatryma* appears to be against any relationship with the Parrots, in which the hind limb has become modified to form a highly specialized climbing and grasping organ, but possibly in the early members of this group these characters had not been acquired, and *Diatryma* may have originated from some such unspecialized form. The earliest fossil Parrot which is definitely known is *Psittacus verreauxii*, Milne-Edwards, from the Lower Miocene of the Allier, France; in this the climbing type of hind limb was already fully developed.

[1] *Journal für Ornithologie*, 1889, p. 236; also *Untersuchungen zur Morphologie und Systematik der Vögel*, p. 1285 et seqq.

Marshall[1] states that remains of Parrots occur in the Eocene of Wyoming, but I have been unable to find any warrant for this statement.

CHAS. W. ANDREWS.

II.—NEW CRETACEOUS GASTROPODA. By BRUCE WADE.

A NOTABLE contribution to the palæontology of the Cretaceous Mollusca has recently been published in the Proceedings of the Academy of Natural Sciences of Philadelphia, vol. lxviii, pt. iii, for 1916–17 (pp. 455–71, pls. xxiii–iv), under the title of "New Genera and Species of Gastropoda from the Upper Cretaceous", by Bruce Wade. The paper is descriptive of a number of elegant shells in a remarkable state of preservation, some having colour as though freshly taken from the sea. The material was collected at Coon Creek, in the north-eastern part of the Nairy County, in west-central Tennessee, from an horizon in the lower part of the Ripley formation. With such excellent material as a basis, several new generic types have been described, and the results will be helpful to those who are familiar with similar shells from other areas, and cognizant therefore of the necessity for the establishment of new divisions. Seven families are represented among the forms described, and there are nine new genera and eleven new species. *Mataxa elegans* is the type of a new genus of the Cancellariidæ; and among the points of difference from *Cancellaria* are the development of a canal, the lack of conspicuous cancellate sculpture, and a less acuminate spire. *Mataxa* includes Stoliczka's *Narona eximia*, from the Cretaceous of Southern India, and is probably near the recent sub-genus *Massyla*. To the Volutidæ are assigned two new genera, *Tectaplica* and *Drilluta*. *Tectaplica* is considered as one of the most primitive of the Volutes, and as ancestrally related to *Volutilithes*, from which it differs in having a shorter spire, with flat sides not interrupted by pronounced shoulders. *Tectaplica simplica* is the genotype. The new name *Drilluta* is a contraction of the names *Drillia* and *Voluta*, and the genus includes a group of Volutes that have been variously described under these names and also under *Fasciolaria* and *Fusus*. The absence of a posterior siphonal notch and the presence of columella plaits distinguish this new genus from *Drillia*, while a lower spire and numerous transverse folds can be noted as points of difference from the typical *Voluta*. *Drilluta* is separated into two well-defined groups: section A (type, *D. communis*, sp. nov.) and section B (type, *D. major*, sp. nov.). The Fusidæ are represented by a new sub-genus *Anomalofusus*, and *Ornopsis*, gen. nov. The new sub-genus resembles *Phos*, but is much more slender, and it differs from *Fusus* in its shorter canal and its thickened and notched outer lip. *Fusus* (*Anomalofusus*) *substriatus* is the type. *Ornopsis glenni* is the type of a genus that bears resemblance to *Latirus* in general outline, and to some of the Buccinidæ in its close compact spire. *Hydrotribulus* (type, *H. nodosus*, sp. nov.) is a new genus, assigned to the Buccinidæ,

[1] *Zoologische Vorträge*, "Die Papagaien," p. 45, Leipzig, 1889.

characterized by a low spiral angle, strong cancellate sculpture, a much inflated body, and by a much excavated and reflected inner lip, which conceals an umbilicus. It has a general resemblance to *Pyrifusus*, and includes a species from the Senonian of Aachen, referred by Müller to the genus *Rapa*, and by Holzapfel to *Tudicla*. Referred to the Euomphalidæ is a shell that has a flattened spire, a deep wide umbilicus, of which the outer margin is conspicuously produced, and an angular peripheral margin. It shows points of resemblance and difference both with *Discohelix* and *Straparollus*, and a new genus, *Hippocampoides* (type, *H. serratus*, sp. nov.), is instituted for it. Representatives of the Turbinidæ and Delphinulidæ are also described. A new genus, *Schizobasis*, is assigned to the former, and the genus *Urceolabrum*, also new, to the latter. *Schizobasis depressa* is the type of a turbiniform genus that is characterized by a short well-defined canal, a feature not found in any other members of the Turbinidæ. A conspicuous circular reinforced aperture, a deep umbilicus, and an elevated cancellate spire are characters that typify *Urceolabrum tuberculatum*, gen. et sp. nov., the genotype of a well-defined group of forms new to the Delphinulidæ. To this new genus is also referred a form described by Müller from the Aachen Beds as *Scalarta*, and afterwards by Holzapfel as *Liotia*.

III.—The Silurian Inlier of Usk. By C. I. Gardiner, M.A., F.G.S.; with a Palæontological Appendix, by F. R. C. Cowper Reed, M.A., D.Sc., F.G.S. Proceedings of the Cotteswold Naturalists Field Club, vol. xix, pp. 129–170, pls. vii and viii and Geological Map.

THE general structure of the inlier consists of two anticlines with a N.N.E.–S.S.W. trend separated from each other by a fault, having the same general direction. The western, or Coed-y-paen, anticline is more important than the eastern, or Llangibby, anticline and brings the Wenlock Shale (the lowest exposed rock) to the surface over a large area. The Wenlock Limestone comes in at a somewhat indeterminate horizon, which is probably not quite the summit of the Wenlock Shale, and over this the Ludlow rocks lie conformably. There is no typical Downtonian, but the basement bed of the Old Red Sandstone overlies the Ludlow with very little discordance in dip. The rocks of the Llangibby anticline as seen at the surface belong almost entirely to the Ludlow series, and only at one place is the Wenlock Limestone exposed; however, three small inliers of Old Red Sandstone are brought in by minor synclines.

Only on the south and west of the Coed-y-paen anticline does the Old Red Sandstone overlie the Ludlow rocks directly; on all other sides wherever it can be seen the boundary of the inlier is a faulted one. The chief of these faults, like that dividing the two anticlines, have a N.N.E.–S.S.W. direction; but there is also another series of faults in a more or less E.–W. direction which are later than the first-named series. These systems of faults must be referred to the Pennine and Armorican foldings respectively, as they affect the Old Red Sandstone as well as the Silurian.

The rocks in this area present quite normal characters; the Wenlock Shale is 850 feet thick, and is composed of mudstones below with sandy shales above, at the base of which the characteristic calcareous concretions are found. Towards the summit it becomes more sandy and passes into the Wenlock Limestone. This rock is only 40 feet thick here and is composed of thin limestone bands with sandy partings, and cannot be called a coral reef. It occurs in isolated strips as it is much broken by the faulting, and has even been pushed into the more yielding shale beds.

The Ludlow Beds are 1,300 feet thick; they pass downwards conformably into the underlying Wenlock, and are composed of impure sandy shales followed by sandstones. There is no Aymestry Limestone nor any sign of the Aymestry fauna, and the Ludlow rocks cannot be divided into an upper and lower series. This great thickness of Ludlow Beds at Usk shows a striking contrast to the Tortworth inlier, where they have been in great part removed by erosion.

In the appendix by Dr. Cowper Reed several new species and varieties are described, including new species of *Chonetes* (*C. ceratoides*), *Pteronitella* (*P. inexpectata*), *Gosseletia* (?) [*G.* (?) *Tawneyi*], *Pholadella* (*P. McCoyi*), and new varieties of *Proetus Stokesi*, Murchison, and *Phacops Stokesi*, Milne Edwards.

The paper is illustrated by a geological map and two plates of photographs of the fossils described by Dr. Cowper Reed.

W. H. Wilcockson.

IV.—Atlantis. By Pierre Termier. Smithsonian Report for 1915, pp. 219–34.

In this publication, which is a translation of a lecture given before the Institut Océanographique of Paris on November 30, 1912, the author puts forward the evidence in favour of accepting the Platonian account of the destruction of Atlantis as materially true. After giving a general account of the old legend, with quotations from Plato's *Timæus*, the author reviews the geological and zoological evidence for the former existence and recent disappearance of the Atlantic Continent. He argues that land must have existed along the lines of the Alpine and Hercynian folds, and also further south along the northern border of the old Gondwanaland, and that this land must have gradually foundered, the old E.–W. lines giving place to the present N.–S. line, as shown by the bank which runs from north to south down the centre of the Atlantic Ocean. This bank, and the similar banks off the coast of Africa, are connected with volcanic and seismological phenomena as shown by the volcanic islands which are situated on them; and the deeps on either side of it bear the same relation to the volcanoes as do the deeps off the western coast of America to the Cordillera of the Andes. The presence of undisturbed Miocene beds in the Azores and Canaries shows that land existed in the neighbourhood of these islands in Miocene times, but the writer regards as the chief point in favour of recent submergence the fact that a cable ship in 1898 dredged up some fragments of tachylyte from the sea bottom about 500 miles

north of the Azores. This, he says, must have solidified on the surface of the land, as it would have solidified at least into a crypto-crystalline condition at the depth of 3,000 m. where it was found. This fact, coupled with the great inequality and rocky character of the ocean floor at this spot, where the ooze only lies in the hollows, shows that the submergence must not only have been recent but also sudden, as there had been no time for the inequalities of the surface to be eroded.

Turning to the zoological evidence, the author quotes work by M. Louis Germain to show, firstly, that the terrestrial fauna of the Azores, Madeira, the Canaries, and Cape Verde Islands is of continental origin, and shows evidences of adaptation to desert conditions. Secondly, that the Quaternary formations of the Canaries and Mauretania contain the same species of *Helix*. Thirdly, that the mollusca of the four archipelagoes have affinities with the Tertiary mollusca of Europe; and, fourthly, that the Oleacinidæ group of pulmonate mollusca is confined to the Mediterranean basin, the Azores, Canaries, Madeira, the West Indies, and Central America. All this evidence seems to demand the existence of a continent connecting Europe and Central America which gradually disappeared, beginning with the westerly portions and leaving the easterly portions till the last, and the author considers that it is quite conceivable, if we take into account the unstable condition of the Atlantic volcanic areas, that the final disappearance may have been witnessed by man, and have been so sudden as to constitute a "cataclysm".

W. H. Wilcockson.

V.—The Earthquake in the Marsica, Central Italy. By Professor Ernesto Mancini. Smithsonian Report for 1915, pp. 215–18.

On January 13, 1915, the Marsica, a district in the southern part of the Aquilian Abruzzi, was devastated by a very severe earthquake. The region of the Marsica which was the epicentre of the disturbance is situated on the line along which, according to the Japanese seismologist Professor Omori, the chief earthquakes in Italy have been distributed. The district is essentially sedimentary and of Karstic origin, so that a volcanic origin is impossible, and the shock seems to have been caused by two separate deep-seated movements which took place either simultaneously or in very quick succession along a line having a north and south trend, some sixty or seventy miles east of Rome. The shock was of such intensity that the seismograph at Rocca di Papa was dismounted, as also would have been the instrument at Rome had it not been provided with special stop screws. The details of the seismic waves have been worked out by Professor Oddone. Their period was 0·7 second, their wave-length 20 metres, and their amplitude 20 centimetres. The damage to buildings was caused by a bulging movement of the ground, accentuated by eddying motions due to the combination of longitudinal and transverse vibrations coming from the hypocentre to the epicentre at the surface.

The number of victims is estimated at 25,000, at Avezzano 10,700 being killed out of a total population of only 13,000.

W. H. Wilcockson.

VI.—La Ligne de Depressions Regna-Verin et ses Sources Carbonatées. By P. Choffat. Extrait du tome xii des Communicações do Serviço Geológico de Portugal. Lisbon, 1917.

THE Gallaico-Durian massif of the North of Portugal is traversed by a curious line of depressions, with which are associated a considerable number of mineral springs particularly rich in carbonates. The country rock consists of Pre-Cambrian schists and Cambrian sediments, both being penetrated by granites, supposed to be of Hercynian age. Although the evidence is not very clear, the springs probably have some genetic connexion with the fractures that determine the lines of depression.

R. H. Rastall.

VII.—The Economic Geology of the Central Coalfield of Scotland. Area VIII: East Kilbride and the Quarter. Mem. Geol. Surv. Scotland. pp. iv+52, 1 fig. and 2 plates, 1917. Price 2*s*.

THIS is the second memoir of a series of which the first was recently noticed in these columns (Geol. Mag., September, 1917, pp. 426–7). It follows precisely the same lines as its predecessor, and contains an interesting account of the strata of the East Kilbride district, which are mostly of Lower Carboniferous age, resting on the plateau basalts. Only at the extreme east of the area is there a small patch of Upper Carboniferous rocks. The very fine sections in Calderwood Glen are described in detail, and special attention is paid to the discovery first made by Mr. Carruthers that here plants of undoubted Calciferous Sandstone age are associated with *Posidonomya Becheri* and *Aviculopecten papyraceus*, thus showing that in Scotland the Pendleside facies occurs very low down in the Lower Carboniferous. At the present time the economic productions of this area are of small value, and the interest is mainly stratigraphical and palæontological.

R. H. R.

VIII.—Molybdenum in Natal.

IN the *South African Journal of Science* for November, 1916, Mr. A. L. du Toit describes a curious occurrence of molybdenum ores in a sandstone belonging to the upper part of the Karroo system (Molteno Series). The molybdenum minerals occur as an impregnation in quite a limited area, in association with iron pyrites and marcasite and some carbonaceous material. The minerals that have been identified are molybdenite, molybdic ochre, and ilsemannite, the two latter being apparently oxidation products of the sulphide. The origin of the deposit is not clear: it does not seem to be detrital, as the patch is well defined from the rest of the rocks; there are no dykes or any indication of channels by which solutions could have

ascended. About 100 feet higher in the Molteno Series is a dolerite sill of the usual Karroo type, and the mineralization may possibly be due to this phase of igneous activity.

R. H. R.

IX.—A remarkable occurrence of Calcite in Silicified Wood. By Edgar T. Wherry. Proceedings of the United States National Museum, vol. liii, pp. 227–30.

In 1915 Mrs. Charles D. Walcott collected in the Yellowstone National Park a piece of silicified wood of *Sequoia magnifica* (Knowlton), in which were numerous white grains with rhombic crystal outlines and dark central inclusions. When thin sections of the wood were examined the grains were found to consist of calcite, occurring sometimes in simple crystals, but more frequently twinned, often polysynthetically. The development of the crystals shows some interesting features. In the centre there is generally an inclusion of woody cells, distorted either very little or not at all, then comes a layer of clear calcite with woody fibre which occasionally extends along the boundaries of the twin lamellæ; outside this, just within the crystal, there is often a zone of disrupted cells, and finally outside the boundaries of the faces, which are often curved, is a dark compact band of tissue. The fibre round the crystals shows little or no distortion, each cell being filled with a single quartz crystal; this shows that the calcite must have been deposited before the quartz and when the wood was so rotten that pressure was not transmitted through it for any distance.

The history of the specimen seems to have been as follows:—The rotten wood was permeated by solutions containing calcium carbonate, which at first deposited calcite quickly at certain places round the cells. Then, later, deposition became slower and the cells were pushed outwards by the growing crystals to form the dark band round the edges. After a break in the deposition a final layer was deposited so as to include some of the broken tissue on the edges of the crystals, and finally the calcareous solutions gave place to siliceous solutions which deposited quartz in the remainder of the tissues.

W. H. Wilcockson.

X.—The Royal Society Club.

In the *Annals of the Royal Society Club, the record of a London dining-club in the eighteenth and nineteenth centuries* (Macmillan, pp. xv, 504, 1917, price 18*s.* net) Sir Archibald Geikie has published a volume packed with biographical interest. Although such a book can at best be but a record of fact, still there is a certain amount of general interest within these covers. From various accounts one gathers that almost from 1650 certain members of the future Royal Society (1662) met together at taverns to discuss their interests, but the earliest surviving document relating to the "Club" dates from October, 1743. Since then the weekly dinner regularly continued for sixty years, and the most curious portion of these records consists in the bills of fare faithfully entered up week by week for more than

forty years of the eighteenth century. Further interest will be found in the names of and notes on the numerous geologists, both British and foreign, who were admitted as guests to the dinners, with the curious un-British arrangement that they had to pay for their own food.

The book demanded wide knowledge and reading, and there are but few slips. Huxley died in 1895, Carpenter (p. 402) was W. B., and Horsley died in Mesopotamia. The statements on p. 428 are unfortunate.

XI.—Brief Notices.

1.—A Contribution to the Invertebrate Fauna of the Oligocene Beds of Flint River, Georgia. By William Healey Dall. Proc. United States Nat. Mus., vol. li, pp. 487–524, with pls. lxxxiii–viii, 1916.

IN this work the author recognizes two zones, an upper and a lower. The former has yielded 61 species, of which 29 are new, while the lower zone has furnished 39 species, among which 9 are new. Five of the new species and 14 of the others are said to be common to both zones. A useful distribution table is given of the fauna showing the occurrences of the various species in both zones and their presence in the Ocala, Vicksburg, Orthaulax, and Chipola horizons. The fauna described is entirely molluscan, comprising Pelecypoda, Gasteropoda, and Scaphopoda.

2.—Mollusks from the type locality of the Choctawhatchee Marl. By Wendell C. Mansfield. Proc. United States Nat. Mus., vol. li, pp. 599–607, pl. cxiii, 1916.

THE fauna here described is made up of Pelecypoda, Gastropoda, and Scaphopoda, having been collected in the Choctawhatchee Marl, regarded as of Miocene age, occurring near Redbay, Walton County, Florida. Descriptions and illustrations are given of the following new species of Pelecypoda: *Arca* (*Scapharca*) *staminea*, Say, new sub-species *rubisiniana*, *Leda choctawhatcheënsis*, *Phacoides* (*Pleurolucina*) *choctawhatcheënsis*, *Astarte* (*Ashtarotha*) *Vaughani*, and *Diplodonta waltonensis*. The complete fauna of this deposit is tabulated so that the range of the species is shown from Oligocene to Pliocene times.

3.—The Shells of the Holderness Basement Clays. By Alfred Bell. *The Naturalist*, 1917, pp. 95–8, 135–8.

THIS paper furnishes a revision of the published lists of Mollusca from these deposits, with criticisms and remarks on the determinations and nomenclature. Of the 180 molluscs recorded, it is stated that at least 100 are no longer living south of the Shetlands, while the remainder mostly belong to Arctic Norway. Relationships of the Mollusca are noticeable in the Bridlington and Chillesford Beds.

4.—New Meteorites.

MR. GEORGE P. MERRILL in the Proceedings of the United States National Museum describes two new meteorites. The one (vol. li, pp. 525–6) is interesting because it was dredged up from Lake Okechobee, Florida, by a fishing net, and may possibly be a fragment of a meteorite which fell in that region about thirteen years ago. The stone is still firm and shows the characteristic crust. Under the microscope the chondritic nature of the stone is at once evident. Altogether the various fragments secured amount to about 1,100 grams. The other meteorite (vol. lii, pp. 419–22) consists of three fairly complete individuals and a fragment, and weighed altogether 7,605 grams. It is of the usual chondritic type, but the finer details of the structure are obscured by oxidation. It was found near Plainview, Hale County, Texas.

OBITUARY.

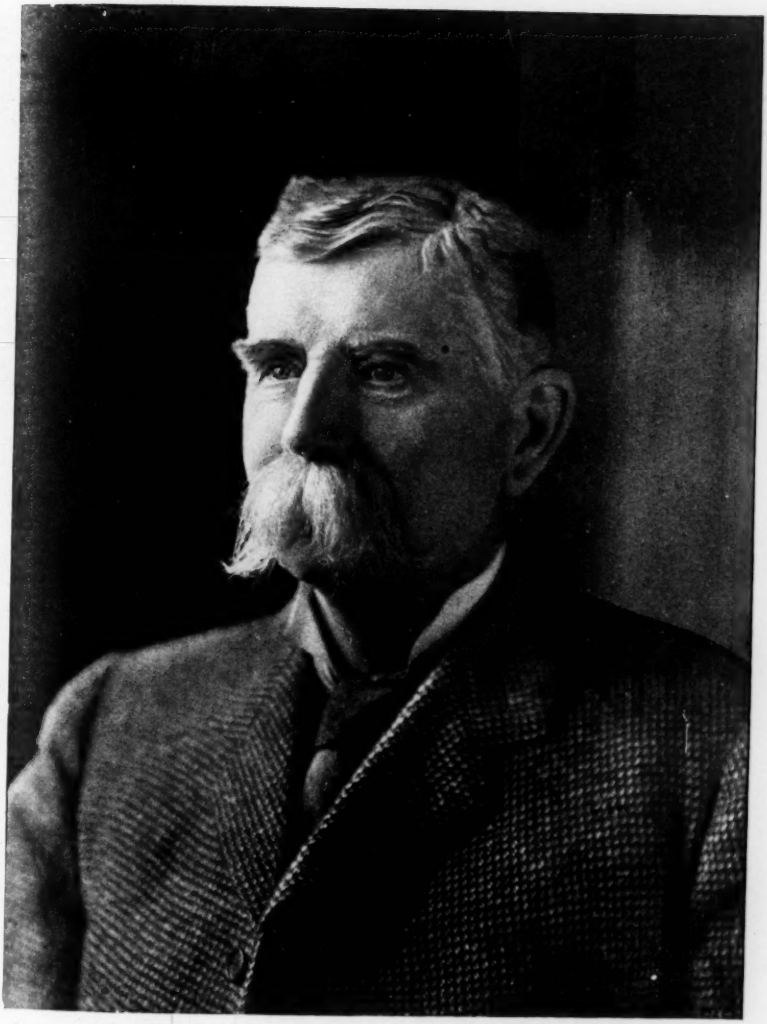
ALFRED NICHOLSON LEEDS, F.G.S.

Born March 9, 1847. Died August 25, 1917.

(WITH A PORTRAIT, PLATE XXXI.)

We regret to have to record the death of Mr. Alfred N. Leeds, one of the most successful pioneers in the modern methods of collecting and preserving fossil vertebrate skeletons. For nearly half a century he had devoted his leisure to recovering the remains of fossil reptiles and fishes from the brickfields in the Oxford Clay near Peterborough; and the thoroughly scientific and painstaking nature of his work can be appreciated at once by a glance at the unique series of specimens which he contributed to the Geological Department of the British Museum (Natural History).

The second son of Mr. Edward Thurlow Leeds, of Eyebury, Peterborough, Alfred Leeds was born in his ancestral home seventy years ago. He was educated at the Warwick Grammar School, and afterwards desired to follow a medical career; but circumstances necessitated his assuming the management of the Eyebury farm, and from 1868 onwards this was his daily occupation. His elder brother, Mr. Charles E. Leeds, who was then studying at Oxford, received encouragement from Professor John Phillips to persevere in the collection of fossils round his home which he had already begun. A large part of a Plesiosaurian skeleton which he had discovered was, indeed, described by Phillips in his *Geology of Oxford and the Thames Valley* (1871). Under such stimulus he was soon joined by Alfred Leeds, and the two brothers gradually perfected methods of extracting the skeletons from the soft clay which were more scientific and thorough than had ever been attempted before. By liberal rewards they induced the workmen not to dig up bones themselves, but to send notice of each discovery to Eyebury. One or both the brothers would then disinter the specimens with their own hands, noting the mode of occurrence of every fragment and clearly distinguishing the



Photo, Lafayette.

Yours faithfully
Alfred E. Lees

parts of each individual skeleton. Next they cleaned, washed, and pieced together the broken fragments at home; and they kept such exact records that if any parts proved to be missing they were able to return to the place of discovery and very often supply the deficiencies. Some of the larger skeletons, in fact, were so widely scattered that they could only be recovered bit by bit in the course of weeks or months as the clay was worked; but the brothers' records were so well kept that even in these difficult cases the missing parts of most remarkable specimens were eventually obtained.

In 1887 Charles Leeds emigrated to New Zealand, where he died in 1912 (see GEOL. MAG., Dec. V, Vol. IX, p. 287). For the last thirty years, therefore, Alfred Leeds worked alone, aided only in the delicate processes of preparing specimens by his accomplished wife and by one of his sons, E. Thurlow Leeds, now of the Ashmolean Museum, Oxford. The scientific value of his results was acknowledged by the Council of the Geological Society in 1893, when they awarded to him part of the Lyell Fund.

Although Mr. Alfred Leeds never ventured himself to write about his discoveries, he soon became well versed in the osteology of the Mesozoic reptiles and thoroughly appreciated most of the novelties which he met with. He handed over all his material, with his own observations, to various specialists who were in friendly communication with him. His collection was thus described by J. W. Hulke, H. G. Seeley, R. Lydekker, C. W. Andrews, and A. S. Woodward, and was also used for reference by O. C. Marsh, G. Baur, and others. Among Dinosaurs he obtained important remains of *Omosaurus* and *Stegosaurus*, and especially fine portions of the skeleton of *Cetiosaurus*, including a fragment of the slender whip-shaped end of the tail like that of the American *Diplodocus*. He was the first to find sufficiently extensive series of *Pliosaurus* to show the true nature of that gigantic marine reptile. He also discovered two closely related new genera, which were named *Peloneustes* and *Simolestes* by Lydekker and Andrews respectively. His wonderful collection of Plesiosaurians and Ichthyosaurians enabled Seeley to determine for the first time the characters of the pectoral arch of these reptiles; and he discovered several growth-stages in the Plesiosaurians as described by Andrews. Among Crocodilians he obtained a unique series of more or less nearly complete skeletons of *Metriorhynchus* and *Steneosaurus*, showing that the former differed from all other known Crocodilians in its complete adaptation to aquatic life, lacking bony scutes, and having the tip of the backbone turned downwards to support a vertical tail-fin as in the Ichthyosaurians. From 1890 onwards all the most important of these specimens were gradually acquired by the British Museum, and an exhaustive *Descriptive Catalogue of the Marine Reptiles*, prepared by Dr. Andrews (with illustrations), was published officially in two volumes in 1910 and 1913.

The fishes discovered by Mr. Leeds were no less important than the reptiles, on account of the manner in which they displayed the separate bones, especially of the head. They include several new species described at different times by Dr. A. S. Woodward. The most striking new genus and species is *Leedsia problematica*, the